ERDA—76/110/4

Fusion Power By Magnetic Confinement Program Plan

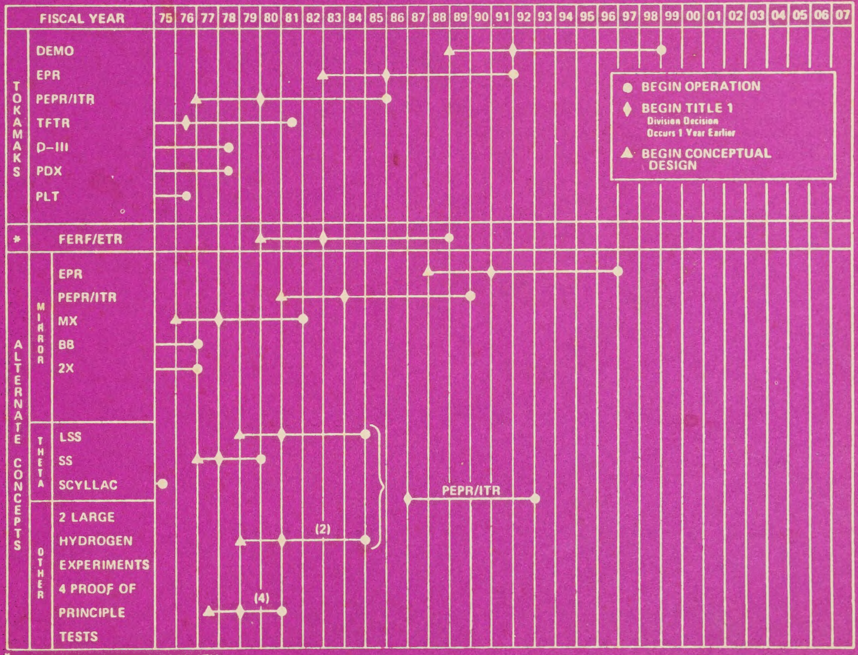
Energy Research & Development Administration
Division Of Magnetic Fusion Energy

July 1976

Volume IV

Five Year Program Budget &
Milestone Summaries

LOGIC III REFERENCE OPTION



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This Program Plan spells out the options available to the Division of Magnetic Fusion Energy under a range of possible funding assumptions called "Program Logics". As such, it represents a Division document and not necessarily the views of the top ERDA management. The Division believes, however, that the range of program logics and options presented will cover any eventualities which may arise in the course of setting program strategies with ERDA management, OMB, and Congress.

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Fusion Power Research and Development Program

5-Year Program

Budget and Milestone Summaries

TABLE OF CONTENTS

Page

Budget Summary 1

Confinement Systems Program 9

Tokamak Systems 9
1. Princeton Large Torus (PLT) 10
2. Neutral Beam Lines for PLT 12
3. ORMAK 13
4. ORMAK-Upgrade 15
5. Alcator 16
6. Alcator C 17
7. Doublet III 18
8. Doublet IIA 19
9. Poloidal Divertor Experiment (and FM-1) 20
10. Adiabatic Toroidal Compressor (ATC) 22
11. Impurity Study Experiment (ISX) 23
12. Other Supporting Experiments 24

Mirror Systems 25
1. 2X-IIB and 2XB 26
2. 2XC 29
3. MX 30
4. BB-IIT 31
5. BB-MB (Baseball-multibeam) 32
6. Mirror Q-enhancement 34
7. LITE 35
8. MRTX (Mirror Reactor Technology Experiment) 37
9. QX 39
10. EBT-I, EBT-S 40
11. EBT-II 42
12. Field-Reversal Theta Pinch (FRTP) 43

Page

High Density Systems 45
1. Scyllac 46
2. Staged Scyllac 48
3. Large Staged Scyllac (LSS) 49
4. Staged Theta Pinch 51
5. Toroidal Z-Pinch (ZT) Program 53
6. Scylla IV-P 55
7. Scylla IV-P/Gun Injection 57
8. Long Linear Experiment (LLX) 58
9. Conceptual Studies 59

Technical Projects Office 60

1. Tokamak Fusion Test Reactor (TFTR) 61
2. Rotating Target Neutron Source-II (RTNS-II) 64
3. Intense Neutron Source (INS) 65

Development and Technology Program 66

Magnetic Systems 66
1. Superconducting Magnets 67
2. Base Program and unselected MDF 72
3. Large Coil Project (MDF) 74
4. High Field Test Facility (MDF) 76
5. Energy Storage and Transfer 78
6. Base Program and unselected MDF 80
7. Superconducting Homopolar Motor-Generators (MDF) 82

Plasma Engineering 84
1. Neutral Beam Development - Base Program 85
2. 150 keV Test Stand (MDF) 89
3. 200 keV High Voltage Test Stand (MDF) 91
4. TFTR Prototype (MDF) 93
5. Advanced Beam Test Facility (ABTF) (MDF) 94
6. Alternate Heating 95
7. Direct Energy Conversion 98
8. Vacuum Component Development 100
9. Plasma Maintenance and Control 102

Page

Fusion Reactor Materials 104
  1. Alloy Development for Irradiation Performance 105
  2. Plasma-Materials Interaction 107
  3. Special Purpose Materials Development 108
  4. Damage Analysis and Dosimetry 109
  5. Radiation Source Development and Operation 111
  6. d(Li,n) High Energy Neutron Source 113
  7. Multi-Beam Radiation Facility (MBRF) 114

Fusion Systems Engineering 115
  1. Advance Design 116
  2. Systems Studies 118
  3. Blanket and Shield 119
  4. Tritium Processing and Control 121
  5. Plasma Systems 123
  6. Plant Systems 124

Environment and Safety 125
  1. Environmental Assessment 126
  2. Facility Safety Analysis 127
  3. Fusion Reactor Safety Research 128

Applied Plasma Physics 129

Theory 127
  1. Plasma Properties 130
  2. Plasma Production and Heating 132
  3. Computer Applications 134
  4. Atomic, Molecular and Nuclear Physics 136
  5. Exploratory Concepts 137

Experimental Plasma Research 138
  1. Plasma Properties 139
  2. Plasma Production and Heating 142
  3. Measurements and Instrumentation 145
  4. Atomic, Molecular and Nuclear Physics 147
  5. Fusion Plasma Research Facility - FPRF 149
  6. Exploratory Concepts 150

Page

National Computer Network 152
  1. Computer Services and Technology 153

Possible Future Experiments 154
  1. LASL HBT 155
  2. Fast Liner Experiment 156

Budget Summary
($ in Thousands)

OPERATING	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982	Total FY 78-82
Fusion Power Research and Development Program	$120,000	$ 37,000	$182,000	$247,100	$280,000	$327,000	$346,000	$376,000	$1,576,100
Confinement Systems Program	61,900	19,300	79,600	110,000	125,000	140,000	140,000	150,000	665,000
Tokamak Systems	43,200	13,800	57,400	70,000	75,000	80,000	80,000	80,000	385,000
Princeton Large Torus (PLT)	10,760	2,200	10,650	14,900	15,000	14,500	14,000	11,000	69,400
Neutral Beam Lines for PLT	900	650	500	0	0	0	0	0	0
ORMAK	4,000	850	2,700	0	0	0	0	0	0
ORMAK Upgrade	200	250	4,800	9,200	9,000	7,000	11,000	11,000	47,200
Alcator	1,500	350	1,350	1,000	0	0	0	0	1,000
Alcator C	200	250	1,850	5,500	4,000	4,000	4,500	12,500	30,500
Doublet III	9,900	4,000	15,700	17,200	22,000	21,000	23,000	16,000	99,200
Doublet IIA	3,000	600	3,300	3,700	2,500	0	0	0	6,200
Poloidal Divertor Experiment (and FM-1)	9,240	4,050	12,950	15,300	10,000	18,000	14,000	11,000	68,300
Adiabatic Toroidal Compressor (ATC)	1,600	0	0	0	0	0	0	0	0
Impurity Study Experiment (ISX)	1,900	550	3,600	3,200	3,500	5,500	3,500	3,500	19,200
Other Supporting Experiments	0	0	0	0	9,000	10,000	10,000	15,000	44,000
Mirror Systems	10,900	3,500	14,000	28,900	36,400	41,100	36,900	40,700	184,000
2X-IIB and 2XB	5,400	1,560	5,100	6,100	7,800	7,900	3,500	3,500	28,800
2XC	0	0	600	1,600	0	0	0	0	1,600
MX	0	150	1,100	3,100	6,800	6,400	11,300	15,000	42,600
BB-IIT	2,150	500	1,800	1,800	0	0	0	0	1,800
BB-MB (Baseball -multibeam)	0	475	1,400	2,300	4,700	5,200	4,500	5,200	21,900
Mirror Q-enhancement	0	0	100	1,500	1,500	1,000	2,000	2,000	9,000
LITE	1,650	425	1,700	2,100	1,900	500	0	0	4,500
MRTX	0	0	0	1,000	1,100	5,200	2,600	3,000	12,900
QX	0	0	0	2,600	3,600	2,200	3,500	5,000	16,900
EBT-I, EBT-S	1,400	350	1,800	2,700	3,000	1,500	500	0	7,700
EBT-II	0	100	200	2,900	5,000	9,000	8,500	7,000	32,400
Field Reversal Theta Pinch (FRTP)	0	0	245	1,200	1,000	1,200	500	0	3,900

	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982	Total FY 78-82
High Density Systems	$ 7,800	$ 2,000	$ 8,200	$ 11,100	$ 13,600	$ 18,900	$ 23,100	$ 29,300	$ 96,000
Scyllac	3,750	950	1,205	900	0	0	0	0	900
Staged Scyllac	0	0	80	5,000	7,000	8,000	7,500	5,500	33,000
Large Staged Scyllac (LSS)	0	0	0	400	1,200	1,200	4,100	6,800	13,700
Staged Theta Pinch	1,400	300	1,100	530	0	0	0	0	530
Toroidal Z-Pinch (ZT) Program	850	300	4,040	2,440	3,100	7,000	8,500	11,300	32,340
Scylla IV-P	1,650	415	1,430	1,250	2,200	2,500	2,500	3,200	11,650
Scylla IV-P/Gun Injection	150	65	240	450	0	0	0	0	450
Long Linear Experiment (LLX)	0	0	0	100	100	200	500	2,500	3,400
Conceptual Studies	150	25	60	30	0	0	0	0	30
Technical Projects	400	800	10,000	18,000	12,000	22,000	25,000	25,000	102,000
Tokamak Fusion Test Reactor (TFTR)	400	800	10,000	15,300	10,300	20,000	23,000	25,000	93,600
Rotating Target Neutron Source-II (RTNS-II)	0	0	0	1,200	0	0	0	0	1,200
Intense Neutron Source (INS)	0	0	0	1,500	1,700	2,000	2,000	0	7,200
Development and Technology Program	33,450	9,230	58,050	75,000	95,000	110,000	126,000	146,000	552,000
Magnetic Systems	7,350	1,850	17,750	19,000	25,000	28,000	32,100	37,200	141,300
Superconducting Magnets	5,200	1,400	15,450	16,400	21,000	23,000	25,100	29,200	114,700
Base Program and Unselected MDF[1]									
Large Coil Project (MDF)[1]									
High Field Test Facility (MDF)[1]									
Energy Storage and Transfer	2,200	450	2,300	2,600	4,000	5,000	7,000	8,000	26,600
Base Program and Unselected MDF[2]									
Superconducting Homopolar Motor-Generators (MDF)[2]									

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[1] Budget Data Aggregated in Superconducting Magnets Subelement

[2] Budget Data Aggregated in Energy Storage & Transfer Subelement

	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982	Total FY 78-82
Plasma Engineering	$ 10,110	$ 3,710	$ 19,700	$ 21,000	$ 25,000	$ 26,000	$ 29,800	$ 34,500	$136,300
Neutral Beam Development-Base Program	5,340	1,500	7,200	7,500	8,500	10,000	12,000	14,500	52,500
150 keV Test Stand	2,250	770	1,500	1,900	2,000	1,500	1,500	1,500	8,400
200 keV High Voltage Test Stand	800	550	1,300	1,500	2,000	2,300	2,500	5,000	13,300
TFTR Prototype	0	350	3,000	4,100	1,500	800	0	0	6,400
Advanced Beam Test Facility	0	0	0	500	3,500	3,500	4,500	3,000	15,000
Alternate Heating	1,492	450	350	2,800	3,500	3,500	4,500	5,000	19,300
Direct Energy Conversion	200	50	400	500	800	800	1,000	1,000	4,100
Vacuum Component Development	30	0	500	700	1,200	1,300	1,300	1,500	6,000
Plasma Maintenance and Control	0	40	1,300	1,500	2,000	2,300	2,500	3,000	11,300
Fusion Reactor Materials	6,870	1,750	9,350	16,000	20,000	23,000	26,300	30,500	115,800
Alloy Development for Irradiation Performance	1,390	360	2,960	5,800	6,800	8,700	11,000	13,000	45,300
Plasma-Materials Interaction	1,630	390	2,050	2,800	3,600	4,500	5,000	5,000	20,900
Special Purpose Materials Development	1,170	260	810	1,000	1,200	1,800	2,300	2,800	9,100
Damage Analysis and Dosimetry	850	260	610	1,000	2,000	2,200	2,500	2,500	10,200
Radiation Source Development and Operation	1,830	480	2,920	5,400	6,400	5,800	5,500	7,200	30,300
d(Li,n) High Energy Neutron Source[3]									
Multi-Beam Radiation Facility[3]									
Fusion Systems Engineering	8,670	1,810	10,300	18,000	23,000	30,000	34,400	39,900	145,300
Advance Design	4,300	730	3,400	8,000	9,500	10,500	12,000	16,000	56,000
Systems Studies	2,810	690	3,500	4,000	4,800	5,550	5,800	6,100	26,250
Blanket and Shield Engineering	490	140	900	1,800	2,800	4,900	5,000	5,000	20,000
Tritium Processing and Control	610	150	1,500	2,300	3,270	3,900	4,950	5,200	19,620
Plasma Systems	330	80	700	1,100	1,300	2,000	2,600	3,000	10,000
Plant Systems	130	20	300	800	1,330	3,150	4,050	4,100	13,430

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[3] Budget Data Aggregated in Radiation Source Development and Operation Subelement

	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982	Total FY 78-82
Environment and Safety	$ 450	$ 110	$ 950	$ 1,000	$ 2,000	$ 3,000	$ 3,400	$ 3,900	$ 13,300
Environmental Analysis	450	110	250	300	700	1,000	600	600	3,200
Facility Safety Analysis	0	0	100	100	300	500	600	900	2,400
Reactor Safety Research	0	0	600	600	100	1,500	2,200	2,400	7,700
Applied Plasma Physics	24,300	7,700	34,400	44,100	48,000	55,000	55,000	55,000	257,100
Fusion Plasma Theory	12,300	3,600	13,600	17,700	21,000	25,000	25,000	25,000	113,700
Plasma Properties	5,000	1,440	5,310	5,630	7,000	8,200	8,300	8,400	37,530
Plasma Production and Heating	500	140	520	1,000	1,220	1,480	1,500	1,500	6,700
Computer Applications	6,470	1,920	7,300	9,000	10,500	12,800	12,850	13,000	58,150
Atomic, Molecular and Nuclear Physics	330	100	470	820	990	1,100	1,000	850	4,760
Exploratory Concepts	0	0	0	1,250	1,290	1,420	1,350	1,250	6,560
Experimental Plasma Research	8,800	3,100	15,800	17,400	18,300	20,000	20,000	20,000	95,700
Plasma Properties	1,590	725	2,125	2,300	2,700	2,800	2,500	2,300	12,600
Plasma Production and Heating	2,660	735	2,380	2,400	2,600	2,800	2,600	2,500	12,900
Measurements and Instrumentation	1,060	340	2,100	2,735	2,950	3,100	2,900	2,700	14,385
Atomic, Molecular and Nuclear Physics	1,290	445	2,000	2,700	3,100	3,500	3,600	3,500	16,400
Exploratory Concepts	2,200	855	4,195	4,265	4,450	5,200	5,700	6,200	25,815
Fusion Plasma Research Facility	0	0	3,000	3,000	2,500	2,600	2,700	2,800	13,600
Computer Services and Technology	3,200	1,000	5,000	9,000	8,700	10,000	10,000	10,000	47,700

EQUIPMENT	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982	Total FY 78-82
Fusion Power Research and Development Program	$ 17,425	$ 4,580	$ 22,860	$ 32,065	$ 44,550	$ 55,260	$ 45,140	$ 55,000	$232,015
Confinement Systems Program	7,700	2,475	8,200	16,225	17,400	17,260	18,490	20,350	89,755
Tokamak Systems	4,458	1,375	5,800	8,550	8,400	9,700	9,800	9,800	46,250
Princeton Large Torus (PLT)	1,330	270	1,020	1,100	2,000	2,000	2,000	2,000	9,100
Neutral Beam Lines for PLT	0	0	0	0	0	0	0	0	0
ORMAK	300	300	300	0	0	0	0	0	0
ORMAK Upgrade	250	125	900	2,300	1,000	1,000	1,000	1,000	6,300
Alcator	300	50	150	150	0	0	0	0	150
Alcator C	0	0	150	150	400	400	500	500	1,950
Doublet III	200	150	1,915	1,750	2,000	2,000	2,000	2,000	9,750
Doublet IIA	800	100	300	500	200	0	0	0	700
Poloidal Divertor Experiment (and FM-1)	780	280	780	2,300	2,000	2,000	2,000	2,000	10,700
Adiabatic Toroidal Compressor (ATC)	40	0	0	0	0	0	0	0	0
Impurity Study Experiment (ISX)	458	100	285	300	300	300	300	300	1,500
Other Supporting Experiments	0	0	0	0	500	2,000	2,000	2,000	6,500
Mirror Systems	2,195	790	1,435	6,620	7,400	5,060	5,590	6,420	31,090
2X-IIB and 2XB	815	325	750	820	600	610	620	630	3,280
2XC	0	0	0	0	0	0	0	0	0
MX	0	0	0	300	2,200	1,800	2,150	3,000	9,450
BB-IIT	335	50	100	800	0	0	0	0	800
BB-MB (Baseball-multibeam)	255	265	100	1,400	1,300	500	550	600	4,350
Mirror Q-enhancement	0	0	50	0	800	600	420	440	2,260
LITE	250	50	100	350	0	0	0	0	350
MRTX	0	0	0	0	500	500	500	500	2,000
QX	0	0	0	0	400	100	500	500	1,500
EBT-I, EBT-S	540	100	300	270	400	100	50	0	820
EBT-II	0	0	0	2,600	1,000	750	750	750	5,850
Field Reversal Theta Pinch (FRTP)	0	0	35	80	200	100	50	0	430

	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982	Total FY 78-82
High Density Systems	$ 1,047	$ 310	$ 965	$ 1,085	$ 1,600	$ 2,500	$ 3,100	$ 4,130	$ 12,415
Scyllac	400	100	160	95	0	0	0	0	95
Staged Scyllac	0	0	10	175	800	1,000	800	600	3,375
Large Staged Scyllac (LSS)	0	0	0	0	200	200	650	1,250	2,300
Staged Theta Pinch	200	60	150	20	0	0	0	0	20
Toroidal Z-Pinch (ZT) Program	75	40	345	190	350	950	1,150	1,500	4,140
Scylla IV-P	372	60	265	370	250	350	400	480	1,850
Scylla IV-P/Gun Injection	0	50	35	75	0	0	0	0	75
Long Linear Experiment (LLX)	0	0	0	160	0	0	100	300	560
Conceptual Studies	0	0	0	0	0	0	0	0	0
Technical Projects	150	50	1,000	2,300	3,500	3,000	1,400	0	10,200
Tokamak Fusion Test Reactor (TFTR)	150	50	1,000	2,000	2,700	2,900	1,300	0	8,900
Rotating Target Neutron Source-II (RTNS-II)	0	0	0	110	0	0	0	0	110
Intense Neutron Source (INS)	0	0	0	190	800	100	100	0	1,190
Development and Technology Program	5,175	1,055	5,660	8,510	15,250	16,000	19,150	19,950	78,860
Magnetic Systems	1,250	320	1,850	2,750	4,850	5,600	7,650	8,950	29,800
Superconducting Magnets	1,010	270	1,600	2,200	4,350	4,900	6,950	7,950	26,350
Base Program and Unselected MDF[1]									
Large Coil Project (MDF)[1]									
High Field Test Facility (MDF)[1]									
Energy Storage and Transfer	240	50	250	500	500	700	700	1,000	3,400

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[1] / Budget Data Aggregated in Superconducting Magnets Subelement

[2] / Budget Data Aggregated in Energy Storage & Transfer Subelement

	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982	Total FY 78-82
Plasma Engineering	2,305	415	2,150	3,100	6,500	6,100	6,500	5,600	27,800
Neutral Beam Development-Base Program	950	140	720	1,000	1,700	1,600	2,000	2,000	8,300
150 keV Test Stand	450	50	100	100	150	100	100	100	550
200 keV High Voltage Test Stand	820	170	300	100	150	100	200	700	1,250
TFTR Prototype	0	0	550	700	500	200	0	0	1,400
Advanced Beam Test Facility	0	0	0	200	2,000	2,000	700	200	5,100
Alternate Heating	70	25	230	750	1,000	1,000	2,000	1,000	5,750
Direct Energy Conversion	15	5	80	50	200	300	500	500	1,550
Vacuum Component Development	0	0	70	80	300	300	300	300	1,280
Plasma Maintenance and Control	0	25	110	120	500	500	700	800	2,620
Fusion Reactor Materials	1,400	210	1,060	1,900	2,900	2,600	3,000	3,300	13,700
Alloy Development for Irradiation Performance	280	30	170	330	900	1,000	1,200	1,300	4,730
Plasma-Materials Interaction	410	80	370	430	500	500	600	600	2,630
Special Purpose Materials Development	240	20	120	80	100	200	200	300	880
Damage Analysis and Dosimetry	180	40	100	30	200	200	300	300	1,030
Radiation Source Development and Operation	290	40	300	1,030	1,200	700	700	800	4,430
d(Li,n) High Energy Neutron Source[3/]									
Multi-Beam Radiation Facility[3/]									
Fusion Systems Engineering	220	60	600	640	800	1,400	1,700	1,700	6,240
Advance Design	30	0	0	0	0	0	0	0	0
Systems Studies	30	0	0	0	0	0	0	0	0
Blanket and Shield Engineering	20	30	60	200	300	500	600	600	2,200
Tritium Processing and Control	120	30	540	250	300	500	600	600	2,250
Plasma Systems	10	0	0	100	100	100	200	200	700
Plant Systems	10	0	0	90	100	300	300	300	1,090

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3 / Budget Data Aggregated in Radiation Source Development and Operation Subelement

	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982	Total FY 78-82
Environment and Safety	$ 0	$ 0	$ 0	$ 120	$ 200	$ 300	$ 300	$ 400	$ 1,320
Environmental Analysis	0	0	0	0	0	50	50	60	160
Facility Safety Analysis	0	0	0	0	0	0	0	0	0
Reactor Safety Research	0	0	0	120	200	250	250	340	1,160
Applied Plasma Physics	4,400	1,000	8,000	5,000	8,400	19,000	6,100	14,700	53,200
Fusion Plasma Theory	0	0	0	0	0	0	0	0	0
Plasma Properties	0	0	0	0	0	0	0	0	0
Plasma Production and Heating	0	0	0	0	0	0	0	0	0
Computer Applications	0	0	0	0	0	0	0	0	0
Atomic, Molecular and Nuclear Physics	0	0	0	0	0	0	0	0	0
Exploratory Concepts	0	0	0	0	0	0	0	0	0
Experimental Plasma Research	2,300	700	2,400	3,000	4,500	4,000	4,000	4,500	20,000
Plasma Properties	625	325	425	400	500	450	350	350	2,050
Plasma Production and Heating	475	125	150	200	400	300	200	200	1,300
Measurements and Instrumentation	375	150	350	400	500	450	350	359	2,050
Atomic, Molecular and Nuclear Physics	125	20	50	100	500	350	250	250	1,450
Exploratory Concepts	700	80	425	900	2,000	1,800	2,150	2,850	9,700
Fusion Plasma Research Facility	0	0	1,000	1,000	600	650	700	500	3,450
Computer Services and Technology	2,100	300	5,600	2,000	3,900	15,000	2,100	10,200	33,200

Confinement Systems Program

Tokamak Systems

Title: Princeton Large Torus (PLT)
Contractor: Princeton Plasma Physics Laboratory
Group Leader: W. Stodiek
DMFE Program Contact: D. W. Ignat

Budget	1976	1976A	1977 Budget	1978	1979	1980	1981	1982	Total 78-82
Normal Operations	6330	1900	8100	11400	11000	11000	11000	11000	55400
Device Fabrication	1880	0	0	0	0	0	0	0	0
Neutral Beam	2550	300	250	0	1500	3500	3000	0	8000
RF	0	0	2300	3500	2500	0	0	0	6000
Total Operation	10760	2200	10650	14900	15000	14500	14000	11000	69400
Equipment	1330	270	1020	1100	2000	2000	2000	2000	9100

Milestones:

1.	Begin machine operations with plasma (MBO)	Dec 1975 (achieved)
2.	Begin coil test	Apr 1976 (achieved)
3.	Obtain definitive data on the question of confinement	Sep 1976
4.	Decide on high power rf heating experiment	Oct 1976
5.	Operate first neutral beam on PLT	Nov 1976
6.	Confirm predictions of equal electron and ion temperature exceeding 1 keV in plasma heated only by toroidal current (MBO)	Dec 1976
7.	Complete installation of fourth neutral beam	Mar 1977
8.	Decide on operation at field > 35 kG	Apr 1977
9.	Obtain definitive data on the matter of raising the ion temperature by 2 keV or more with neutral beam injection	Sep 1977
10.	Test 3 x 10^5cm/sec pellet injection on PLT	Jun 1978
11.	Complete installation of high power rf heating system	Jul 1979

Summary:

The design parameters for PLT are such that the simultaneous conditions of high density, high plasma temperature, and long energy confinement times should be approached in a large volume tokamak for the first time. The experiment should provide necessary information on the scaling laws of tokamaks.

The expectations for the performance of PLT depend on the assumptions made about plasma behavior. In designing the device, the following assumptions were made: (1) the

Summary:
(continued)

diffusion would be 30 times less advantageous than so-called "pseudoclassical" law, which itself is about 10 times less favorable than the predictions of classical theory. ("Classical" means that cooperative effects do not enhance the fundamental diffusion caused by single particle collisions.) (2) The plasma would carry 1.6 MA and remain grossly stable. (3) The level of impurities would be low ($Z_{eff} \approx 2$). These three assumptions lead to the conclusion that with ohmic heating alone, $T_e = T_i = 2.5$ keV and $\tau_E = 0.3$ sec. Neutral beam injection of about 4 megawatts into PLT will supplement the ohmic heating in 1977. If the plasma responds favorably to the neutral beam heating process, it may be possible to obtain ion temperatures in the 5 keV range.

In PLT, plasmas are expected to be in a collisionless regime in which trapped particle effects can become important and dominate the scaling. The even more collisionless regime characteristic of an operating fusion reactor will be reached at ion temperatures above 4 keV, according to present theoretical estimates and the assumptions of a fairly low level of impurities.

The PLT experiment is expected to begin operation by December 1975. For the first year, ohmic heating experiments will dominate the experimental program and a great deal of knowledge will be obtained on MHD stability, microscopic transport, impurity effects and the general behavior of large diameter high current plasmas. Preliminary experiments on rf heating are planned for the first two years, in continuation of the work on ST, the device decommissioned in May of 1974 to make room for PLT. For this work, existing power supplies and generators (25 MHz, 2 MW) will be used.

Neutral beam heating of PLT will begin in FY 1977, making extensive use of the technology now being developed at ORNL and LBL/LLL for high current ion sources at 40 keV. The 4 MW of neutral beam power will come from the supply approved by DCTR in October 1974. Increased voltage and power is planned for operation in 1981.

Fiscal year 1979 will see the addition of high power rf heating with the aid of supplies funded under "RF" in the table. It is very likely that both rf and neutral beam experiments will proceed at the same time on PLT.

Experimental work on PLT is now expected to extend into the early 1980's, with a variety of investigations of neutral beam and rf heating, impurity control, and two component simulation relevant to the TFTR.

Title: Neutral Beam Lines for PLT
Contractor: Oak Ridge National Laboratory and Princeton Plasma Physics Laboratory
Group Leaders: L. Stewart (ORNL),
H. Eubank (PPPL)
DMFE Program Contact: D. W. Ignat, J. W. Beal

Budget	1976	1976A	1977 Budget	1978	1979	1980	1981	1982	Total 78-82
MDF	900	650	500	0	0	0	0	0	0
Equipment	0	0	0	0	0	0	0	0	0

Milestones:

1.	Operate test facility at ORNL	Aug 1976
2.	Delivery of developmental source to PPPL	Sep 1976
3.	Delivery of beam line to PPPL	Oct 1976
4.	Operate tested beam line and source on PLT	Nov 1976
5.	Operate second beam line on PLT	Dec 1976
6.	Operate third and fourth beam lines on PLT	Mar 1977

Summary: These four neutral beam lines, designed to inject 600-900 kW each when used in conjunction with the ORNL 40 kV, 50A sources, are being built and tested at ORNL. When operated on PLT, this system is projected to produce 4-5 keV plasma temperatures.

*ORNL, PPPL, and DMFE recognizes that these milestones have been set with minimal contingency and the project is proceeding on a highest priority basis.

Title: ORMAK
Contractor: Oak Ridge National Laboratory
Group Leader: Lee Berry
DMFE Program Contact: D. W. Ignat, T. Hsu

Budget	1976	1976A	1977 Budget	1978	1979	1980	1981	1982	Total 78-82
Normal Operations	3500	850	2700	0	0	0	0	0	0
Device Fabrication	500	0	0	0	0	0	0	0	0
Total Operations	4000	850	2700	0	0	0	0	0	0
Equipment	300	300	300	0	0	0	0	0	0

Milestones:

1.	Begin operation at higher magnetic field (~ 33 kG) with concurrent operation at higher current (~ 200 kA)	Jul 1976
2.	Increase injected power to 500 kW	Nov 1976
3.	Begin pellet injection with Illinois apparatus	Nov 1976
4.	Complete preliminary experiments with 500 kW injection power	Dec 1976
5.	Evaluate operation at ~ 33 kG with higher plasma current (~ 200 kA)	Feb 1977
6.	Complete evaluation of experiments with 500 kW injection power	Feb 1977
7.	Complete ORMAK program	Apr 1977

Summary: ORMAK (Oak Ridge Tokamak) is a confinement experiment designed to investigate tokamak scaling laws and the effectiveness of neutral beam heating of plasma ions in a tokamak geometry. It has successfully demonstrated that the plasma confinement typical of smaller tokamaks can be scaled-up to devices of larger size and smaller aspect ratio (ratio of major to minor radius of the torus)--necessary conditions for future fusion reactors. Special emphasis in ORMAK research is being given to experiments aimed at demonstrating the effectiveness of neutral beam heating. Results of these experiments have been significant: the ion temperature has been raised from 500 eV to more than 1500 eV with neutral powers over 300 kW. This result is from January 1976, and progress is rapid. In February, the Division of Controlled Thermonuclear Research approved the

Summary:
(continued)

ORMAK-Upgrade experiment: a 40 kG tokamak of 30 cm minor radius and plasma current up to 800 kA with 2 MW of neutral beam heating power. Funding limitations of FY 76-76T have caused a slower than desired start on ORMAK-Upgrade and a consequent delay in completion to late 1978.

The primary programmatic role of ORMAK-Upgrade will be the investigation of high power density heating from neutral beams on plasma equilibrium, stability, density and beta.

Title: ORMAK-Upgrade
Contractor: Oak Ridge National Laboratory
Group Leader: L. Berry
DMFE Program Contact: D. W. Ignat, T. Hsu

Budget	1976	1976A	1977 Budget	1978	1979	1980	1981	1982	Total 78-82
Normal Operations	0	0	1500	4950	7000	7000	7000	7000	32950
Device Fabrication	200	250	3300	2850	0	0	0	0	2850
Neutral Beam	0	0	0	1400	2000	0	0	0	3400
RF	0	0	0	0	0	0	4000	4000	8000
Total Operation	200	250	4800	9200	9000	7000	11000	11000	47200
Equipment	250	125	900	2300	1000	1000	1000	1000	6300

Milestones:

1.	Complete specifications for TF coil copper	Apr 1976 (achieved)
2.	Order TF coil copper	Jul 1976
3.	Complete design of TF coils	Jul 1976
4.	Order TF coils	Sep 1976
5.	Order VF power supply	Sep 1976
6.	Order vacuum vessel	Dec 1976
7.	Order OH/VF coils	Feb 1977
8.	Receive VF power supply	Jul 1977
9.	Receive TF coils and vacuum vessel	Jul 1977
10.	Receive OH/VF coils	Sep 1977
11.	Complete installation of TF coils and vacuum vessel	Oct 1977
12.	Complete fabrication of two beam lines	Feb 1978
13.	Complete test stand checkout of two beam lines	Feb 1978
14.	Begin machine operation with plasma	Apr 1978
15.	Begin operation with injection (2 MW total available)	Oct 1978
16.	Evaluate injection experiment	Aug 1979

Summary: ORMAK-Upgrade is to be a 40 kG tokamak with a 30 cm minor radius, plasma current capability of up to 800 kA, and 2 MW of neutral beam injection power with the access for up to 4 MW. As such, ORMAK-Upgrade will provide high power density beam heating at a modest cost ($7.3M total). Projected plasma temperatures range from 3 keV to 7 keV, depending on density, impurities and transport. Present plans call for an increase in power to 4 MW in 1979 and a 2 MW ECRH system in 1982.

Title: Alcator
Contractor: Massachusetts Institute of Technology
Principal
Investigator: Bruno Coppi
Group Leader: Ron Parker
DMFE Program Contact: J. W. Willis

Budget	1976	1976A	1977 Budget	1978	1979	1980	1981	1982	Total 78-82
Normal Operations	1500	350	1350	1000	0	0	0	0	1000
Equipment	300	50	150	150	0	0	0	0	150

Milestones:

1. Install submillimeter laser interferometer	Jul 1976
2. Evaluate 75 kG operation	Sep 1976
3. Begin 90 kG operation	Oct 1976
4. Evaluate 90 kG operation	Jan 1977
5. Begin LHRH experiment at ~ 125 kW	Jan 1977
6. Decide on future of Alcator A	Mar 1977

Summary: The high field tokamak, Alcator, has advanced into a region of parameter space still unreached in other devices by producing a plasma current of 200 kA in a 9 cm radius plasma with a toroidal magnetic field of 60 kG. The resulting record-high current density coupled with neutral gas injection has produced an unusually wide range of operating conditions. At 70 kG, a record value of $n\tau \approx 10^{13}$ has been achieved at peak density of 6×10^{14} cm^{-3} with plasma temperature of 1 keV. The Alcator magnet has been tested at 100 kG -- nearly twice that available in standard tokamaks and operation at this level is planned.

Title: Alcator C
Contractor: Massachusetts Institute of Technology
Principal Investigators: B. Coppi
Group Leader: R. Parker
DMFE Program Contact: J. W. Willis

Budget	1976	1976A	1977 Budget	1978	1979	1980	1981	1982	Total 78-82
Normal Operations	0	0	850	1500	3000	3000	3000	3000	13500
Device Fabrication	200	250	1000	1500	0	0	0	0	1500
Power Supply	0	0	0	2500	0	0	0	0	2500
RF	0	0	0	0	1000	1000	0	0	2000
Upgrade	0	0	0	0	0	0	1500	9500	11000
Total Operation	200	250	1850	5500	4000	4000	4500	12500	30500
Equipment	0	0	150	150	400	400	500	500	1950

Milestones:

	Milestone	Date
1.	Receive TF Coil Plate materials	Aug 1976
2.	Receive first finished TF turns	Sep 1976
3.	Receive last finished TF turns	Apr 1977
4.	Receive vacuum chamber components	Jan 1977
5.	Start TF coil and vacuum chamber assembly	Jan 1977
6.	Complete TF coil and vacuum chamber assembly	Sep 1977
7.	Receive OH and EF coils	Oct 1977
8.	Complete machine assembly	Mar 1978
9.	Start moderate field operation (< 85 kG)	Apr 1978
10.	Installation and checkout of new OH supply	Jul 1978
11.	Installation and checkout of new TF supply	Aug 1978
12.	Start high field operation (< 140 kG)	Oct 1978

Summary: The next generation Alcator device will be approximately twice the size of the existing machine with a minor radius of 17 cm and improved access for diagnostics (or RF heating if desirable). The B device would have a magnet set optimized to the existing Magnet Lab power supply and could reach 100 kG. With the addition of a new power supply, the C device magnet set could reach 140 kG. Either device will test scaling of the high field, high current density concept at larger size, higher field, and hotter temperatures. An RF heating system (exact method unspecified) is planned for 1981 and an upgrade to longer pulse or larger size is planned to operate in the middle 80's.

Title: Doublet III
Contractor: General Atomic Co.
Group Leader: J. Gilleland
DMFE Program Contact: R. A. Blanken

Budget	1976	1976A	1977 Budget	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	1200	500	4200	8640	10000	10000	10000	10000	48640
Device Fabrication	8700	3500	11300	2560	0	0	0	0	2560
Neutral Beam	0	0	200	6000	9000	4000	6000	6000	31000
Upgrade	0	0	0	0	3000	7000	7000	0	17000
Total Operation	9900	4000	15700	17200	22000	21000	23000	16000	99200
Equipment	200	150	1915	1750	2000	2000	2000	2000	9750

Milestones:

1.	Award contract for vacuum vessel	Jul 1976
2.	Complete center post assembly	Jan 1977
3.	Complete preparation of diagnostics for initial operation of Doublet III	Dec 1977
4.	Begin experiments	Feb 1978
5.	Assemble and test first neutral injector for Doublet III	Oct 1978
6.	Evaluate plasma confinement	Dec 1978
7.	Decide on Doublet III Upgrade	Jan 1979
8.	Begin neutral injection experiments (4 MW)	Jul 1979
9.	Evaluate auxiliary heating	Apr 1980
10.	Initial operation of Doublet III Upgrade	Jun 1981

Summary: The Doublet III, approved late in 1974, is to be a large device, similar in concept to Doublet IIA. Based on the success of Doublet II and phased to take advantage of the results from Doublet IIA, Doublet III will provide reactor-like conditions for a comparison of the various cross-section configurations. Doublet III is expected to operate with $n\tau$ approaching 10^{14} cm^{-3} sec, a temperature of 2 keV with ohmic heating and, with neutral beam heating, a temperature near 5 keV. With initial operation scheduled for early 1978, the estimated cost of fabrication is $27,700,000. Funds for Doublet III Upgrade will add additional power supplies to increase the toroidal field and plasma current; fabrication is expected to start in 1979, be completed in 1981 and cost $17,000,000.

Title: Doublet IIA
Contractor: General Atomic Co.
Group Leader: T. Tamano

DMFE Program Contact: R. A. Blanken

Budget	1976	1976A	1977 Budget	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	2600	600	3300	3700	2500	0	0	0	6200
MDF	400	0	0	0	0	0	0	0	0
Total Operation	3000	600	3300	3700	2500	0	0	0	6200
Equipment	800	100	300	500	200	0	0	0	700

Milestones:

1. Obtain detailed measurements of plasma profiles and impurities	Jul 1976
2. Initiate experiments at higher magnetic field	Dec 1976
3. GA submit future program plan for Doublet IIA	May 1977
4. Begin rf heating experiments	Sep 1977
5. Decision point on future of Doublet IIA	Sep 1977

Summary: In FY 1974, Doublet II demonstrated tokamak-like operation in a torus with a non-circular cross-section plasma, the "kidney-shaped" doublet configuration. In July 1974, a modification of this device was completed in which discrete coils replaced the doublet-shaped shell, allowing the formation of plasmas with circular and elongated cross-sections as well as the doublet plasmas. This modified device, called Doublet IIA, also allows improved diagnostic access to the plasma. Experiments are being performed to study the parameters associated with different plasma cross-sections. An rf heating experiment near the lower hybrid resonant frequency is also planned. The expectation is that the doublet configuration will allow a given toroidal magnetic field to contain a larger plasma pressure than is possible in a circular cross-section device. Such a result would indicate an economic advantage for larger tokamak reactors.

Title: Poloidal Divertor Experiment (and FM-1)
Contractor: PPPL
Group Leader: Dale Meade, James Sinnis, John Schmidt DMFE Program Contact: J. W Willis

Budget	1976	1976A	1977 Budget	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	2470	1350	7200	10900	10000	10000	10000	11000	51900
Device Fabrication	6770	2700	5100	2100	0	0	0	0	2100
Neutral Beam	0	0	650	2300	0	5000	2000	0	9300
Upgrade	0	0	0	0	0	3000	2000	0	5000
Total Operation	9240	4050	12950	15300	10000	18000	14000	11000	68300
Equipment	780	280	780	2300	2000	2000	2000	2000	10300

Milestones:

	Milestone	Date
1.	Complete fabrication of first divertor coil	Nov 1976
2.	Complete fabrication of toroidal field coils	Jan 1977
3.	Complete subassembly of vacuum vessel and poloidal coil assembly	Apr 1977
4.	Complete power test	Oct 1977
5.	Begin operation	Apr 1978
6.	Evaluate divertor operation in ohmically heated plasma	Dec 1978
7.	Begin neutral injection experiments	Dec 1978
8.	Evaluate stability of D shaped plasma	Apr 1979
9.	Operate 3 x 10^5 cm/sec pellet injector on PDX	Jun 1979
10.	Evaluate divertor operation with neutral injection	Aug 1979
11.	Decide on optimized divertor design	Oct 1979
12.	Operate optimized divertor	Apr 1981

Summary: The Poloidal Divertor Experiment (PDX), approved late in FY 1974, will be a large tokamak in which a variety of magnetic divertor configurations and plasma startup modes will be tested as methods for reducing impurities in large high-temperature tokamaks. Impurities are created when energetic particles strike the walls of the tokamaks; high concentrations of impurities could result in shorter energy containment time and a requirement of higher temperature for ignition, both resulting in higher costs for reactors. In the PDX, plasma particles diffusing toward the walls will be swept along diverted field lines into regions where they can be captured or pumped away before they can interact with the walls. Similarly, impurities approaching

Summary:
(continued)

the plasma from the wall will also be diverted to the region where they can be eliminated. With full funding beginning in FY 1975, PDX is scheduled for completion by April 1978 at a cost of $18,800,000. Information from the first year of PDX operation will determine the essential features of divertor operation, allowing the design of an optimized divertor system to proceed in mid-FY 1979. This optimized system would serve as a prototype divertor for EPR-1 and would begin providing information in FY 1981.

Title: Adiabatic Toroidal Compressor (ATC)
Contractor: Princeton Plasma Physics Laboratory
Group Leader: R. Ellis
DMFE Program Contact: J. W. Willis

Budget	1976	1976A	1977 Budget	1978	1979	1980	1981	1982	Total 78-82
Operation	1600	0	0	0	0	0	0	0	0
Equipment	40	0	0	0	0	0	0	0	0

Milestones:		
1.	Shutdown ATC	July 1976
2.	Evaluate ICRH and LHRH experiments	Aug 1976

Summary: ATC has been used to test various heating methods, compression, neutral injection, and RF. Experiments have also been conducted on impurity transport and impurity control by gettering. ATC will be dismantled in July 1976 to make room for PDX.

Title: Impurity Study Experiment (ISX)
Contractor: ORNL and General Atomic Company
Group Leaders: Tom Jernigan (ORNL) and Keith Burrell (GA)

Budget	1976	1976A	1977 Budget	1978	1979	1980	1981	1982	Total 78-82
Normal Operations									
ORNL	300	100	2500	2700	2700	3000	3000	3000	14400
GA	100	50	500	500	500	500	500	500	2500
RF	0	0	0	0	300	2000	0	0	2300
Total	400	150	3000	3200	3500	5500	3500	3500	19200
Device Fab. (ORNL)	1500	400	600	0	0	0	0	0	0
Total Operations	1900	550	3600	3200	3500	5500	3500	3500	19200
Equipment									
ORNL	458	100	200	200	200	200	200	200	1000
GA	0	0	85	100	100	100	100	100	500
Total	458	100	285	300	300	300	300	300	1500

Milestones:

1.	Order TF coils	Jan 1976 (achieved)
2.	Receive OH transformer core	Aug 1976
3.	Begin magnetic field tests	Nov 1976
4.	Operate ISX	Feb 1977
5.	Evaluate gas flow impurity reversal technique	Jan 1978

Summary: The Oak Ridge National Laboratory has proposed a small device called ISX (Impurity Study Experiment) to be built at Oak Ridge and to be jointly designed and operated with the General Atomic Company. This tokamak will have plasma parameters close to those of the present (20 kG) ORMAK but it will feature great flexibility in terms of access and in terms of the possibility to modify or change the vacuum chamber. The access will facilitate the development and use of diagnostics to study impurity transport; changeability of the vacuum chamber will allow investigation of the advantages and disadvantages of various materials for impurity reduction. Although the ISX will operate with moderate plasma parameters, it will approximate the edge or corona region of a larger, hotter discharge. Therefore, information from this device will be available for wall optimization in larger devices. In 1981 emphasis on ISX will shift to initial investigation of ECRH on tokamaks with the application of 500 kW of power at 60 GHz.

Title: Other Supporting Experiments
Contractor: Undetermined
Group Leader: Undetermined

DMFE Program Contact: N. A. Davies

Budget	1976	1976A	1977 Budget	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	0	0	0	0	2000	6000	7000	10000	25000
Device Fabrication	0	0	0	0	7000	4000	3000	5000	19000
Total Operation	0	0	0	0	9000	10000	10000	15000	44000
Equipment	0	0	0	0	500	2000	2000	2000	6500

Summary: As situations develop in CTR during the coming five years, additional projects will be required which cannot be clearly identified at present. It is expected that there will be a need for small devices at the laboratories to aid in the development of diagnostics and to test new ideas believed unsuitable for early pursuit on large programmatic machines, for example, a medium sized tokamak dedicated to RF heating experiments or to testing the concept of ripple injection.

Confinement Systems Program

Mirror Systems

Title: 2X-IIB and 2XB
Contractor: Lawrence Livermore Laboratory
Group Leader: Fred Coensgen
DMFE Program Contact W. Ellis and M. Johnson

Fiscal Years

Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	4850	1560	5100	5100	6800	6900	3500	3500	25800
Device Fabrication	550	0	0	1000[a]	1000[a]	1000[a]	0	0	3000
Total	5400	1560	5100	6100	7800	7900	3500	3500	28800
Equipment	815	325	750	820	600	610	620	630	3280

[a] $3000K for capacitor bank modifications (see milestone 13)

Milestones:		
1.	Achieve November 1972 physics goals a. higher density ($\epsilon = \omega_{pi}^2/\omega_{ci}^2 > 100$) b. $n\tau = 10^{11} cm^{-3} sec$ c. T_i = 10 keV	July-December 1975 (achieved)
2.	Sustain plasma with beams	July-December 1975 (achieved- 1 ms July 1975 5 ms Feb. 1976)
3.	Shutdown 2X-IIB for conversion to 2XB	May 1976 (achieved)
4.	Design and fabricate	July 1976
5.	Add power crowbar to 2X-IIB power supply to hold magnetic field constant for 10 msec and upgrade neutral beam performance	August 1976
6.	Increase energy of 6 (out of 12) neutral beams from 15-20 keV to 35-40 keV	September 1976
7.	Begin high β plasma experiments in 2XB	September 1976
8.	Extend $n\tau$ (T_i) scaling from 13 keV to 20 keV	October 1976

Title: 2X-IIB and 2XB (continued)

Milestones:

9.	Improve vacuum system. Change neutral beam apertures to permit investigation of large diameter plasmas. Modify gun-generated plasma stream to allow increase of target plasma diameter.	January 1977
10.	Increase radial dimension of plasma from $R/\rho_i = 2-4$ to $5-10$	March 1977
11.	Complete building and testing the 80-kV, 80A neutral beam power supply	August 1977
12.	Shutdown 2XB for conversion to 2XC	April 1978
13.	Begin upgrade of 2X capacitor bank	April 1978
14.	Begin investigation of average-minimum-B stability with new magnet set	October 1978
15.	Test adiabaticity of 80-keV ions from prototype 80-kV neutral beam in 2X high-beta plasma	November 1978
16.	Investigate effect of broadening the energy distribution, using the 80-kV neutral beam	January 1979

Summary:

2XB is a modification of the existing 2X-IIB facility to incorporate a power crowbar for the main magnet capacitor bank, LN_2-cooled liners in the neutral beam source tanks to improve the vacuum performance, and enlarged neutral beam and plasma stream ports to allow investigation of larger diameter plasmas for longer times.

Recent experimental and theoretical developments in the 2X program have been very encouraging. The plasma startup problem appears to have been successfully overcome by the use of high power neutral beams. 2X-IIB has achieved plasma betas or order unity, ion temperatures of 13 keV, densities above 10^{13}cm^{-3} and $n\tau$ values of $10^{11}\text{cm}^{-3}\text{s}$. The 2XB device will extend $n\tau(T_i)$ scaling to 20 keV and allow study of larger diameter plasmas.

Title: 2X-IIB and 2XB (continued)

Summary: Subsequent experiments, using the 2XC magnet set, will examine the question of plasma stability limits in an average-minimum-B geometry (as opposed to absolute-minimum-B in the traditional 2X Yin-Yang coils). Using an 80-kV neutral beam, the prototype of the MX sustaining beams, 2X will explore questions of adiabaticity of high energy ions in a magnetic well, and distribution function tailoring using different combinations of beam energies.

Title: 2XC
Contractor: Lawrence Livermore Laboratory
Group Leader: Fred Coensgen DMFE Program Contact· W. Ellis and M. Johnson

Budget:

	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	0	0	0	0	0	0	0	0	0
Device Fabrication	0	0	600	1600	0	0	0	0	1600
Total Operation	0	0	600	1600	0	0	0	0	1600
Equipment	0	0	0	0	0	0	0	0	0

Fiscal Years

Milestones:

1.	Begin detailed engineering design of 2XC	October 1976
2.	Begin 2XC magnet construction	December 1976
3.	Complete 2XC magnet construction	March 1978
4.	Complete 2XC facility installation	June 1978
5.	Complete 2XC checkout and begin plasma operation	September 1978

Summary: The 2XC magnet modification will allow different magnetic field geometries to be explored in 2X. In particular, plasma stability limits in an average-minimum-B geometry will be studied intensively. The present 2X Ying-Yang magnet set provides an absolute-minimum-B geometry, which, while good for MHD stability is not as economical for reactor applications as some other configurations which will be tested.

Title: MX
Contractor: Lawrence Livermore Laboratory
Group Leader: Fred Coensgen
DMFE Program Contact: W. Ellis and M. Johnson

	Fiscal Years								
Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	0	150	1100	2840	3000	2000	10000	15000	32840
Device Fabrication	0	0	0	260	3800	4400	1300	0	9760
Total Operation	0	150	1100	3100	6800	6400	11300	15000	42600
Equipment	0	0	0	300	2200	1800	2150	3000	9450
Line Item Construction (TEC: 100M)	0	0	0	30M	35M	20M	0	0	85M

Milestones:	1. Review of MX proposal	May 1976
	2. DMFE decision on MX proposal	July 1976
	3. Begin system checkout	April 1981
	4. Begin plasma experiments	September 1981

Summary: MX is a proposed device representing the next large step in the mirror program. It is generally recognized that a large physics experiment is needed to extend the 2X parameter scaling into a regime closer to that in a mirror fusion reactor, and to serve as a test bed for technology and engineering advances. MX will employ a large superconducting magnet and quasi-DC, 80-kV, 80-amp neutral beams to generate high temperature, high beta plasmas having larger size scaling than is achievable in existing devices.

If funded in FY 1978 as a line item, MX will begin plasma experiments in 1981. MX is a crucial step in the progress of the magnetic mirror concept towards a fusion reactor.

Title: BB-IIT
Contractor: Lawrence Livermore Laboratory
Group Leader: Charlie Damm
DMFE Program Contact: W. Ellis and M. Johnson

	Fiscal Years								
Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	2150	500	1800	1800	0	0	0	0	1800
Device Fabrication	0	0	0	0	0	0	0	0	0
Total Operation	2150	500	1800	1800	0	0	0	0	1800
Equipment	335	50	100	800	0	0	0	0	800

Milestones:*

1.	Checkout 20 kV, 50 amp neutral beam and gun-generated plasma stream	January 1976 (achieved)
2.	Checkout 300J CO_2 laser system and NH_3 pellet system in BB-IIT tank without magnet	March 1976 (achieved)
3.	Begin experiments on pellet irradiation in BB-IIT tank without magnet	March 1976
4.	Begin experiments on pellet irradiation and plasma buildup with magnet, 300J laser, and 20-kV, 50-amp neutral beam	August 1976
5.	Upgrade diagnostics by adding Thomson scattering and an ion energy analyzer	November 1976
6.	Evaluate laser pellet method of target plasma production	January 1977
7.	Shutdown BB-IIT for conversion to BB-MB	January 1977

Summary:

The BB-IIT experiment is an absolute minimum-B magnetic mirror facility with a DC, superconducting baseball magnet having 90 cm between mirrors, a maximum center field of 15 kG, a mirror ratio of 2 and a well depth of 2. Both laser-produced and gun-injected plasmas will serve as the target plasma for buildup with a 20 kV, 50 amp, 10 ms duration neutral beam. BB-IIT will be converted into a high-power neutral beam mirror experiment, BB-MB, in early 1977.

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*Contingent upon BB-MB funding by July 1976

Title: BB-MB (Baseball-multibeam)
Contractor: Lawrence Livermore Laboratory
Group Leader: Charlie Damm
DMFE Program Contact: W. Ellis and M. Johnson

	Fiscal Years								
Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	0	0	0	1000	3700	4200	4500	5200	18600
Device Fabrication	0	475	1400	1300	1000	1000	0	0	3300
Total Operation	0	475	1400	2300	4700	5200	4500	5200	21900
Equipment									
Normal	0	0	0	0	400	500	550	600	2050
MDF	255	265	100	1400	900	0	0	0	2300
Total Equipment	255	265	100	1400	1300	500	550	600	4350

Milestones:*

1.	Technical review of BB-MB proposal	December 1975	(achieved)
2.	Begin design of 50-kV sustaining beam system (two 50-kV, 35-amp beams)	March 1976	(achieved)
3.	DCTR decision on revised BB-MB proposal	April 1976	(achieved June 1976)
4.	Complete design of BB-MB vacuum tanks and gettered liners, and release for fabrication	May 1976	(achieved June 1976)
5.	Complete design of 20-kV start-up system (four 20-kV, 50-amp beams)	September 1976	
6.	Begin installation of BB-MB vacuum tanks, liners, and 4-beam 20-kV start-up system	January 1977	
7.	Complete design of 50-kV sustaining beam system.	February 1977	
8.	Complete installation of 20-kV start-up system.	March 1977	
9.	Begin plasma experiments in BB-MB with 20-kV start-up beams	May 1977	
10.	Re-evaluate laser-pellet system in context of target plasma plus start-up beams	September 1977	

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*Contingent upon BB-MB funding by July 1976

Milestones:	11.	Complete installation of 50-kV sustaining beam system	September 1977
	12.	Begin plasma experiments in BB-MB with start-up plus sustaining beams	November 1977
	13.	Preliminary evaluation of quasi-steady-state (≥ 0.5 sec) operation in mirror systems	March 1978

Summary: The BB-MB experiment is designed to explore steady-state operation of a magnetic mirror system. The BB-MB experiment will utilize the existing BB-II-T superconducting magnet and will upgrade both the neutral beam injection capability and the vacuum systems. The neutral beam system will provide three additional 20-keV, 50A, 10-ms sources for the plasma buildup experiment. Two 50-keV, 35A, 0.5-sec sources will provide the neutral particle current necessary to sustain the hot plasma. These modifications will provide an experiment capable of exploring the physics and technology assoicated with hot plasma confinement in a truly steady-state magnetic field. The associated requirements on the neutral beam and vacuum technology under steady-state operating conditions will constitute a major portion of the experimental program.

Title: Mirror Q-enhancement
Contractor: Lawrence Livermore Laboratory
Group Leader: Fred Coensgen

DMFE Program Contact: W. Ellis and M. Johnson

Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
	Fiscal Years								
Normal Operation	0	0	100	750	800	1500	2000	2000	7050
Device Fabrication	0	0	0	750	700	500	0	0	1950
Total Operation	0	0	100	1500	1500	2000	2000	2000	9000
Equipment	0	0	50	0	800	600	420	440	2260

Milestones:

1.	Evaluate Q-enhancement techniques	October 1976
2.	Begin construction of Q-enhancement experiment	January 1977
3.	Evaluate physics results	

Summary:

In order for a pure fusion mirror reactor to be economically attractive, the plasma Q, defined as the ratio of fusion power out to neutral beam power in, should have a value of 2-3, or even larger. In a "classical" open-ended mirror system, where the ion confinement time is limited by ion-ion scattering into the loss cone, the optimum plasma Q is approximately unity, and less than the required value of 2-3. A variety of Q-enhancement techniques have been proposed to increase the Q of a mirror system into the desired range of $Q \geq 2$. These techniques include magnetic field reversal, electrostatic end-stoppering, RF end-stoppering, two component mirrors, linear multiple mirrors, a toroidal link for the electrons, and toroidal multiple mirrors. Some of these techniques can be initially studied in existing machines, but there is also a need for an expanded physics program to address Q-enhancement methods in new experimental facilities. The mirror Q-enhancement project will address the initial evaluation, both theoretical and experimental, of Q-enhancement proposals for existing and new experimental facilities.

Title: LITE
Contractor: United Technologies Research Center
Group Leader: Dick Tomlinson DMFE Program Contact: W. Ellis and T. George

Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
	Fiscal Years								
Normal Operation	1650	425	1700	2100	1900	500	0	0	4500
Device Fabrication	0	0	0	0	0	0	0	0	0
Total Operation	1650	425	1700	2100	1900	500	0	0	4500
Equipment	250	50	100	350[a]	0	0	0	0	350

[a] diagnostic equipment

Milestones:

1.	Demonstrate electrical capture and suspension in hard vacuum, of 100μ LiH target pellets	September 1975 (achieved)
2.	Begin pellet irradiation experiments with 2 beam, 100J Nd-glass laser	September 1975 (achieved)
3.	Begin plasma buildup experiments with above target plasma using a 10-kV, 1A neutral beam	October 1975 (achieved)
4.	Begin experiments to stabilize target plasma with low energy ion beam (7 cm ORNL source)	May 1976
5.	DCTR assessment of UTRC program roles in CTR	July 1976
6.	Begin beam line testing with ORNL 20-kV, 15-amp ion source	September 1976
7.	Begin plasma buildup experiments using the 20-kV, 15-amp neutral beam	November 1976
8.	Begin instability control physics investigations on stabilized plasma	June 1977
9.	Begin test stand operation of 50-kV, 50-A beam (shared milestone with MRTX)	June 1977

Title: LITE (con't)

Milestones:

10.	Begin plasma buildup experiments using the 50-kV, 50-A neutral beam	October 1977
11.	Begin plasma stabilization investigations in high density, injection-sustained LITE plasma	June 1978
12.	Evaluate results of laser target initiation plasma stabilization, and buildup in LITE	July 1979
13.	Shutdown LITE for conversion to QX (Q-enhancement experiment)	December 1979

Summary:

The LITE (Laser Initiated Target Experiment) facility at United Technologies Research Center employs a quasi-DC (1-2 s) magnetic mirror field produced by a LN_2 chilled baseball magnet with 30 cm between mirror points, a maximum center field of 15 kG, and a mirror ratio and well depth of 2. The device is initially filled by a laser produced plasma which serves as the target for a steady-state, 10-kV neutral hydrogen beam. The LITE experiment has addressed startup of a mirror device by investigating laser/pellet target plasma production, capture, volume filling, and confinement with plasmas generated by Nd-glass laser irradiation of solid, LiH particles electrically suspended in a hard vacuum inside established magnetic mirror fields. The buildup of hot ion (12 keV) population upon injection of continuous, low current (< 1A) neutral beams into these target plasmas has been demonstrated. Future plans call for investigation of long duration plasma stabilization, heating, buildup, and sustenance with higher current (15-50A), higher energy (25-50 kV) neutral beams. The injection-sustained plasma will be used to conduct physics investigations of plasma instability control and long-duration wall reflux and plasma-erosion studies.

Title: MRTX (Mirror Reactor Technology Experiment)
Contractor: United Technologies Research Center
Group Leader: Alan F. Haught DMFE Program Contact: W. Ellis and T. George

	Fiscal Years								
Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	0	0	0	1000	1100	3200	2600	3000	10900
Device Fabrication	0	0	0	0	0	2000	0	0	2000
Total Operation	0	0	0	1000	1100	5200	2600	3000	12900
Equipment	0	0	0	0	500	500	500	500	2000
Line Item Construction	0	0	0	0	12400	4700	0	0	17100

Milestones:*

1. Submit MRTX draft proposal	May 1976 (achieved)
2. Begin engineering design of MRTX*	October 1976
3. Review MRTX proposal	March 1977
4. DCTR decision point	May 1977
5. Begin test stand operation of 50-A, 50-kV beam (shared milestone with LITE)	June 1977
6. Begin construction of MRTX magnet and neutral beam lines	October 1977
7. Begin MRTX machine checkout	March 1980
8. Begin plasma experiments	October 1980

Summary: The Mirror Reactor Technology Experiment (MRTX) is an intermediate scale ($R_p/\rho_i \sim 10$, 170 cm between mirror points) steady-state, mirror physics experiment for the investigation of long term (multi-minute) injection-sustained mirror plasma operation and is specifically designed with the access and flexibility to permit economic development of critical elements of mirror reactor technology.

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*Contingent upon funding in FY 1977

Title: MRTX (con't)

Summary: These include steady-state energetic neutral beam injection, sequential pumping module operation for continuous vacuum capability, selective leakage magnet geometry, wall loading, and direct conversion studies. The long duration of the experiment will permit operational evaluation of the energetic particle saturation of cryogenic absorption panel pumping and the continuous plasma source will provide a loss-cone distribution plasma beam for direct conversion investigations and a plasma flux up to 20 kW/cm^2 for wall interaction studies at reactor scale surface loadings. MRTX and MX together are intended as a complementary and intensive scientific and technological attack on some of the outstanding magnetic mirror problems in the path of a fusion reactor.

Title: QX
Contractor: United Technologies Research Center
Group Leader: Alan Haught DMFE Program Contact: W. Ellis and T. George

	Fiscal Years								
Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	0	0	0	0	0	1200	2500	5000	8700
Device Fabrication	0	0	0	2600[a]	3600[a]	1000	1000[b]	0	8200
Total Operation	0	0	0	2600	3600	2200	3500	5000	16900
Equipment	0	0	0	0	400	100	500	500	1500

[a] four neutral beam lines at 50-kV, 50-amp each; $2600K for power supply and $3600K for facility

[b] single, high current, 5-10 kV neutral beam for plasma sustenance in field reversal case

Milestones:*

1. Submit QX draft proposal	December 1976
2. Begin engineering design of QX	March 1977
3. Review QX proposal	July 1977
4. DCTR decision point	August 1977
5. Initiate construction of QX magnet and neutral beam lines	October 1977
6. Begin QX machine checkout	October 1979
7. Begin plasma experiments	March 1980

Summary: QX (Q-enhancement Experiment) will have the goal of investigating field reversal in mirrors or other techniques for reducing end loss and/or improving the plasma Q in a mirror system. The details of this experiment are not yet fixed.

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*Contingent upon funding in FY 1977

Title: EBT-I, EBT-S
Contractor: Oak Ridge National Laboratory
Group Leader: Ray Dandl
DMFE Program Contact: W. Ellis and A. Kadish

	Fiscal Years								
Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	1400	350	1800	2200	2500	1500	500	0	6700
Device Fabrication	0	0	0	500	500	0	0	0	1000
Total Operation	1400	350	1800	2700	3000	1500	500	0	7700
Equipment	300	100	300	270	400	100	50	0	820

Milestones:	1. ORNL submission of EBT Program Plan	November 1975 (achieved)
	2. EBT Program Review	November 1975 (achieved)
	3. Profile measurements of plasma parameters (n_e, T_e, T_i, plasma potential) in EBT-I	
	a. Begin measurements	April 1976 (achieved)
	b. Complete installation and checkout of 18-GHz, 60-kW CW, ECH power supply	May 1976 (achieved)
	c. Evaluate results	April 1977
	4 Conversion to high power EBT-S experiment	
	a. Complete development of 25-GHz/200-kW source	April 1977
	b. Install 25-GHz/200-kW source	June 1977
	c. Begin plasma experiments	August 1977
	d. Demonstrate high power heating capability	November 1977
	e. Evaluate results of n_e, T_e scaling with power	March 1978

Summary:

EBT is a continuously operating device in which plasma heating is achieved by tens of kW of CW microwaves primarily at electron cyclotron resonance. It is designed to produce high-beta plasma confinement in a multiple mirror toroidal geometry. MHD stability of the steady state toroidal plasma contained in EBT has been demonstrated already. The significant plasma parameters defining the operating regime are $T_i \approx 75$ eV, $n_e \approx 2\text{-}4 \times 10^{12}$, and $T_e \approx 0.5\text{-}2$ keV with 30 kW of 18.6 GHz microwave power. In the next series of experiments, the power level will be increased to 60 kW and profile measurements of plasma parameters will be made. These experiments will be followed with EBT-S

Title: EBT-I, EBT-S (continued)

Summary: which is a modification of EBT-I involving higher magnetic fields and microwave sources with higher power and frequency than those utilized on EBT-I. As the experiments on EBT-S phase down in 1980-81, the next generation device, EBT-II, will become operational Future fusion power plants utilizing the EBT concept are attractive as energy sources for commercial enterprises for the projected comparatively-low capital investment required for construction. Should the EBT concept achieve its long term goals, controlled fusion could be produced in relatively small scale devices.

Title: EBT-II
Contractor: Oak Ridge National Laboratory
Group Leader: Ray Dandl
DMFE Program Contact: W. Ellis and A. Kadish

	Fiscal Years								
Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	0	100	200	1300	2000	4000	6000	5500	18800
Device Fabrication	0	0	0	1600	3000	5000	2500	1500	13600
Total Operation	0	100	200	2900	5000	9000	8500	7000	32400
Equipment	0	0	0	2600	1000	750	750	750	5850

Milestones:

1. Initiate conceptual design	February 1976 (achieved)
2. Begin detailed design	July 1976
3. Submit EBT-II proposal	January 1977
4. Complete review of EBT-II	July 1977
5. DMFE decision point	September 1977
6. Start construction of EBT-II	January 1978
7. Complete construction	March 1980
8. Begin plasma experiments	July 1980

Summary:

EBT-II will be a high-density, high temperature extension of the "bumpy torus" concept studied in the EBT-I and EBT-S devices. The expected steady state parameters for EBT-II are: $n_e \sim 5 \times 10^{13}$, $T_e \sim 10$ keV, $T_i \sim 2$ keV, $\beta \sim 0.02$. The magnetic field at the mid-plane of the mirror axis, produced by superconducting coils, will be 35 kG with a 2:1 mirror ratio and a 20:1 aspect ratio. The bulk heating microwave source will operate at 120 GHz and 1 MW c.w. and the microwave source for profile heating will operate at 90 GHz and 250 kW c.w. The results from this experiment will provide the first significant test of the scaling laws for the EBT concept, and thus will represent a major step in the EBT program.

Title: Field-Reversal Theta Pinch (FRTP)
Contractor: Los Alamos Scientific Laboratory
Group Leader: Keith Thomas
DMFE Program Contact: W. Ellis and A. Kadish

Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	0	0	245	500	700	1200	500	0	2900
Device Fabrication	0	0	0	700	300	0	0	0	1000
Total Operation	0	0	245	1200	1000	1200	500	0	3900
Equipment	0	0	35	80	200	100	50	0	430

Fiscal Years

Milestones:

1.	DMFE decision point	August 1976
2.	Begin conversion of Scylla IC for RFTP experiment	October 1976
3.	Begin plasma experiments	March 1977
4.	Evaluate initial results	October 1977
5.	DMFE decision point	December 1977
6.	Begin construction of 1 MJ system	January 1978
7.	Begin experiments in the 1 MJ system	June 1978

Summary:

The purpose of the proposed Field-Reversal Theta Pinch (FRTP) experiment is to study methods for setting-up and sustaining a reversed-field theta-pinch configuration. This configuration has the attractive feature of producing a closed field-line magnetic trap. Closed field lines would be very beneficial in reducing particle and energy axial transport in open systems, specifically the linear theta pinch. However, field reversal has potential application to many other confinement systems. For example the plasma currents and field lines in the FRTP are similar to those of a toroidal configuration, such as a tokamak, with a divertor and a noncircular cross-section, but without a toroidal magnetic field. Since the principal deficiency of a tokamak reactor is the poor utilization of the toroidal field (i.e., low toroidal beta), the potential advantage of the FRTP is clear. Field reversal is similarly proposed as a mean of increasing the Q of a magnetic mirror fusion reactor. Field-reversed configurations have application to the Astron concept which is under

Title: Field-Reversal Theta Pinch (FRTP) (continued)

Summary: investigation at Cornell, and to the toroidal Z-pinch program at LASL. Very encouraging experimental results from a field-reversed pinch have been reported by Kurtmullaev at the Kurchatov Institute at Krasnya Pachra. Initial experiments are scheduled to begin in FY 1977, and will be directed toward a confirmation of Kurtmullaev's results. If successful, the FRTP facility will be used to explore field-reversed configurations and plasma transport problems relevant to open-ended mirrors.

Confinement Systems Program

High Density Systems

Title: Scyllac
Contractor: Los Alamos Scientific Laboratory
Group Leader: Warren Quinn
DMFE Program Contact: **W. Ellis and E. Oktay**

	Fiscal Years								Total
Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	78-82
Normal Operation	3750	950	1205	900	0	0	0	0	900
Device Fabrication	0	0	0	0	0	0	0	0	0
Total Operation	3750	950	1205	900	0	0	0	0	900
Equipment	400	100	160	95	0	0	0	0	95

Milestones:

1. Feedback experiments with smooth bore (i.e. non-helical) discharge tubes
   - a. Begin plasma experiments — **December 1975 (achieved)**
   - b. Evaluate results — **June 1976 (achieved)**
2. Feedback experiments with helical discharge tube and $\delta_1 = 1.4$
   - a. Install helical tube — **June 1976 (achieved)**
   - b. Begin plasma experiments — **July 1976 (achieved)**
   - c. Evaluate results — Oct. 1976
3. Feedback experiments with helical discharge tube and $\delta_1 = 3$
   - a. Begin fabrication of coil and tube — May 1976
   - b. Begin installation of coil and tube — Oct. 1976
   - c. Begin plasma experiments — Dec. 1976
   - d. Evaluate results — July 1977
4. Program decision point — August 1977

Summary: **The Scyllac experiment is designed to investigate plasma equilibrium and stability in a toroidal theta pinch. The device has demonstrated plasma production and heating to $T_e + T_i \sim 1.3$ keV, densities of $\sim 3 \times 10^{16}\,\mathrm{cm}^{-3}$, and plasma betas in the 0.5-0.9**

Title: Scyllac (continued)

Summary: range, in the presence of toroidal curvature, and with $\ell = 1$ and $\ell = 0$ multipole fields applied for equilibrium. Experiments have been conducted in various toroidal sectors and in a full torus of major radius 4.0-m. Results show the formation of a hot, well-defined plasma column which achieves an equilibrium configuration as predicted by theory. The theoretically predicted $m = 1$ instability (a gross sideward motion of the plasma column) is seen experimentally and a feedback stabilization system has been developed and installed to overcome this problem. Initial results with the feedback system and auxiliary capacitor-driven ℓ-windings show success in overcoming certain unstable plasma motions. New experimental directions include the use of a helically shaped quartz discharge tube to minimize the problems of achieving equilibrium and reduce feedback requirements. In addition, experiments which substitute $\ell = 1,2$ equilibria for the $\ell = 0,1$ configuration will also be performed. The new equilibria will exhibit a shorter response time to feedback stabilization than those currently employed.

Title: Staged Scyllac
Contractor: Los Alamos Scientific Laboratory
Group Leader: Warren Quinn
DMFE Program Contact: W. Ellis and E. Oktay

Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	0	0	80	1000	3000	5000	6500	4500	20000
Device Fabrication	0	0	0	4000	4000	3000	1000	1000	13000
Total Operation	0	0	80	5000	7000	8000	7500	5500	33000
Equipment	0	0	10	175	800	1000	800	600	3375

Fiscal Years

Milestones:

1. Begin prototype design	October 1976
2. DMFE decision point	August 1977
3. Begin prototype construction	September 1977
4. Begin major construction	March 1978
5. Complete construction and begin checkout	April 1980
6. Begin plasma operation	June 1980

Summary: Staged Scyllac is the next step in the toroidal theta pinch program beyond Scyllac. Its purpose is to explore the physics and technology base required to design, construct, and operate LSS (Large Staged Scyllac), a toroidal theta pinch experiment in the $100M class. Staged Scyllac would combine the results obtained from the Scyllac and Staged Theta Pinch experiments to produce a hot, wall-stabilized, "fat" plasma in an "inside-out" toroidal geometry utilizing the Scyllac bank and a separate high-voltage shock-heating circuit. Feedback stabilization will also be employed to extend the plasma confinement time beyond that allowed by the finite resistivity of the wall. The parameter which is most crucial to the wall stabilization experiment [aimed at achieving stabilization of the gross $m = 1$ (sideward) mode by the presence of a nearby conducting wall] is the ratio of plasma radius to wall radius. Optimization of this ratio is an important ingredient in the process of the Scyllac concept to a fusion reactor. If approval for Staged Scyllac is forthcoming at the end of the present series of Scyllac feedback experiments, plasma experiments would begin in 1980.

Title: Large Staged Scyllac (LSS)
Contractor: Los Alamos Scientific Laboratory
Group Leader: Unspecified
DMFE Program Contact: W. Ellis

	Fiscal Years								
Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	0	0	0	400	1200	1200	2700	6000	11500
Device Fabrication	0	0	0	0	0	0	1400	800	2200
Total Operation	0	0	0	400	1200	1200	4100	6800	13700
Equipment	0	0	0	0	200	200	650	1250	2300
Line Item Construction (TEC 100M)	0	0	0	0	0	0	0	39600	39600

Milestones:

1. Begin conceptual design	October 1977
2. Complete conceptual design	June 1979
3. DMFE decision point	October 1980
4. Complete Title I preliminary design	July 1981
5. Begin building construction	March 1982
6. Complete building construction	September 1983
7. Complete device assembly	April 1985
8. Complete checkout and begin plasma operation	July 1985
9. Shut down LSS for conversion to SFTR	August 1987

Summary: Large Staged Scyllac (LSS) is a proposed confinement device of 40-m major radius (the same as SFTR) which will provide plasmas with the following characteristics: (a) temperatures will be in the keV region; (b) there will be no end effects; (c) the feedback parameter $\gamma\tau$ will be about 0.2; (d) the required wall stabilization parameter (ratio of plasma radius to wall radius) for $m = 1$ stability will have an easily attainable value of approximately 0.4; (e) the finite-Larmor-radius criterion for $m \geq 2$ stability will be amply satisfied. Thus on a technological scale much less than that of SFTR, Scyllac confinement physics could be proven. In addition, the confinement time would be extended to the 1-ms range, so that long-time-scale radial transport effects, as well as neutral gas and impurity interactions with the dense plasma core, can be investigated under conditions where $n\tau = 10^{13}$ sec cm^{-3}.

Title: Large Staged Scyllac (LSS) (continued)

Summary: LSS has two technological aspects: (a) a 40-m radius version of the Staged Scyllac with the same pulse-forming networks for shock heating, and a Scyllac-type staging capacitor bank to provide approximately 100 μs confining fields at 15 to 20 kG; and (b) an additional power crowbar using low-voltage, high-energy-density capacitors (essentially the transfer capacitors of SFTR) to provide extended confinement and further compression of the plasma for 1-ms at approximately 35 kG. A decision to proceed with LSS on the above time table will depend on favorable results from the theta pinch program and the availability of funding.

Title: Staged Theta Pinch
Contractor: Los Alamos Scientific Laboratory
Group Leader: Keith Thomas

DMFE Program Contact: W. Ellis and E. Oktay

Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
				Fiscal Years					
Normal Operation	1400	300	1100	530	0	0	0	0	530
Device Fabrication	0	0	0	0	0	0	0	0	0
Total Operation	1400	300	1100	530	0	0	0	0	530
Equipment	200	60	150	20	0	0	0	0	20

Milestones:

1.	Begin operation of Staged Theta Pinch (4.5-m)	June 1975 (achieved)
2.	Begin staging experiments with cylindrical tube and 3 banks to give a step function current wave form	Dec. 1975 (achieved)
3.	Evaluate staging experiments with a cylindrical tube	Sept. 1976
4.	Begin wall stabilization experiments using $\ell = 1$ fields and helical tube	Oct. 1976
5.	Evaluate initial wall stabilization experiments	July 1977

Summary: The purpose of the Staged Theta Pinch experiment is to separate and study the two phases of heating in theta pinches, shock heating and adiabatic compression in a rising magnetic field. Previous theta pinch experiments have achieved initial shock, or implosion, heating of the ions and subsequent adiabatic compression into the multi-keV range by using a single capacitor bank as the power supply. Projected theta pinch experiments, such as Staged Scyllac and LSS, and toroidal theta pinch reactors, will require separation and control of the two heating phases to achieve greater implosion heating and less adiabatic compression. The resulting "fat" plasma has a large ratio of plasma radius to wall radius, which is advantageous from economic considerations and essential for effective

Title: Staged Theta Pinch (continued)

Summary: wall stabilization of the $m = 1$ (sideward) mode. The experiments will initially involve studies of staging and heating in a smooth bore (cylindrical) coil and discharge tube. Subsequent experiments, planned for late 1976 and 1977, will involve staging studies in conjunction with helical discharge tubes and applied $\ell = 1$ fields to induce the $m = 1$ instability. Investigation of wall stabilization will be a primary purpose of these experiments. The Staged Theta Pinch will be phased out of the program in 1978 when its goals have been accomplished.

Title: Toroidal Z-Pinch (ZT) Program
Contractor: Los Alamos Scientific Laboratory
Group Leader: Don Baker
DMFE Program Contact: W. Ellis and A. Kadish

	Fiscal Years								
Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
ZT-1, ZT-S									
Normal Operation	850	300	530	300	0	0	0	0	300
Device Fabrication	0	0	0	0	0	0	0	0	0
Total Operation	850	300	530	300	0	0	0	0	300
Equipment	75	40	100	40	0	0	0	0	40
ZT-P									
Normal Operation	0	0	1000	2140	2300	2500	1000	0	7940
Device Fabrication	0	0	2510	0	0	0	0	0	0
Total Operation	0	0	3510	2140	2300	2500	1000	0	7940
Equipment	0	0	245	150	350	350	150	0	1000
ZT-II									
Normal Operation	0	0	0	0	800	3500	5000	6300	15600
Device Fabrication	0	0	0	0	0	1000	2500	5000	8500
Total Operation	0	0	0	0	800	4500	7500	11300	24100
Equipment	0	0	0	0	0	600	1000	1500	3100
Line Item Construction (TEC 25M)	0	0	0	0	0	0	10000	15000	25000
ZT TOTALS									
Normal Operation	850	300	1530	2440	3100	6000	6000	6300	23840
Device Fabrication	0	0	2510	0	0	1000	2500	5000	8500
Total Operation	850	300	4040	2440	3100	7000	8500	11300	32340
Equipment	75	40	345	190	350	950	1150	1500	4140
Line Item Construction (TEC 25M)	0	0	0	0	0	0	10000	15000	25000

Title: Toroidal Z-Pinch (ZT) Program (continued)

Milestones:

1.	Review of ZT Program	December 1975 (achieved)
2.	Begin operation of ZT-S	December 1975 (achieved)
3.	Evaluate results from ZT-S	July 1976
4.	Review of ZT-P proposal	July 1976
5.	Begin construction of ZT-P	October 1976
6.	Begin checkout and operation of ZT-P	April 1978
7.	Evaluate results from ZT-P	April 1979
8.	Begin design of ZT-II	February 1979
9.	Review of ZT-II proposal	May 1979
10.	DMFE decision on ZT-II	June 1979

Summary: ZT-S is an axisymmetric high-beta experiment whose primary mission is to investigate the scaling of plasma confinement time as a function of minor radius. ZT-S is a modification of the ZT-1 toroidal Z-pinch to incorporate an increased minor radius and improved electrical circuit. The ZT-1 experiment overcome the temperature limitations of earlier Z-pinches and confirmed the existence of theoretically predicted, stable, high-beta, reversed-field MHD equilibria. In July 1974, ZT-1 achieved confinement times of about 10 μsec with an ion temperature of 100 eV and number density of 10^{15}cm^{-3}. The confinement time in ZT-1 was diffusion limited. It is expected that ZT-S, by virtue of its larger bore, will increase the confinement time by a factor of two with ion temperatures which are limited only by MHD stability criteria. The ZT-S results will be reviewed in July 1976 to determine the future course of the reversed field pinch program. The larger ZT-P and ZT-II experiments are currently projected.

Title: Scylla IV-P
Contractor: Los Alamos Scientific Laboratory
Group Leader: Warren Quinn
DMFE Program Contact: W. Ellis and E. Oktay

	Fiscal Year								
Budget:*	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	850	415	1230	950	2200	2500	2500	3200	11350
Device Fabrication	800	0	200	300	0	0	0	0	300
Total Operation	1650	415	1430	1250	2200	2500	2500	3200	11650
Equipment	372	60	265	370	250	350	400	480	1850

Milestones:

1.	Begin machine checkout	September 1975 (achieved)
2.	Complete machine checkout and begin plasma operation	January 1976 (achieved)
3.	Begin initial experiments - plasma parameter measurements, end-loss studies [e.g., $\beta(z,t)$, $T_e(r,z,t)$, global particle inventory vs. time, etc.]	February 1976 (achieved)
4.	Evaluate initial experiments	August 1976
5.	Begin material end-stoppering experiments (e.g., dense gas plugs, cold plasma plugs, D_2 ice, etc.)	September 1976
6.	Evaluate material end-plug experiments	April 1977
7.	Begin electromagnetic end-stoppering experiments	May 1977
8.	Evaluate end-stoppering experiments	January 1978
9.	Begin high-field, high-density experiments in conjunction with gun-injection studies.	January 1978

Summary:

Scylla IV-P is a 5-meter linear theta pinch capable of producing reactor grade plasmas (T_i = several keV, $n \sim$ few x 10^{16}cm^{-3}, $\beta \sim 1$). Scylla IV-P will be used to study specifically linear theta pinch physics problems, such as particle end-loss, axial thermal conduction, and high field operation. The linear theta pinch is a very attractive fusion reactor candidate because of its relative ease of plasma heating, its favorable plasma equilibrium and stability properties, and its simple geometry. The major problem, of course, is end-loss, whereby, without magnetic mirrors, the

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* This budget is part of the total Scylla IV-P budget

Title: Scylla IV-P (continued)

Summary: plasma particles stream out of the ends at essentially the ion thermal velocity. Without steps to correct this situation, a fusion reactor would be many kilometers in length. Scylla IV-P will be used to study a variety of end-stoppering techniques, employing both material and magnetic barriers. In addition, a variety of other end effects will be studied, including "area waves," axial thermal conduction, line-tying effects, and column rotation. Future plans call for operation at high values of the magnetic field, several hundred kilogauss, to investigate high density plasma formation and confinement problems, and the technology of high-field coil development. The Scylla IV-P experiment will provide the necessary physics and technology foundation upon which to build the much larger LLX (Long Linear Experiment)

Title: Scylla IV-P/Gun Injection
Contractor: Los Alamos Scientific Laboratory
Group Leader: Art Sherwood
DMFE Program Contact: W. Ellis and E. Oktay

Budget:*	Fiscal Years 1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
Normal Operation	150	65	240	450	0	0	0	0	450
Device Fabrication	0	0	0	0	0	0	0	0	0
Total Operation	150	65	240	450	0	0	0	0	450
Equipment	0	50	35	75	0	0	0	0	75

Milestones:

1. Complete construction of plasma gun	May 1976
2. Experiments on the plasma gun performance	
a. Begin experiments	June 1976
b. Evaluate results	January 1977
3. Experiments on the plasma gun injection into a slow solenoid	
a. Begin experiments	March 1977
b. Evaluate results	September 1977
4. Install gun injection experiment on Scylla IV-P	December 1977
5. Begin plasma experiments	January 1978

Summary: The Plasma Gun Injection Experiment is designed to investigate the possibility of plasma injection through the end or ends of a long linear theta pinch for end-stoppering. In addition it is aimed at the development of coaxial guns for the use in producing hot initial plasma for compression in a linear theta pinch. The plasma gun program will have two main phases: a) gun development and study of injection processes in a slow pulsed solenoid; and b) injection into Scylla IV-P for initial plasma production and end-stoppering studies. This project will merge with the Scylla IV-P program after the development of the guns is completed on a 4-m long slow pulsed solenoid.

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* This budget is part of the total Scylla IV-P budget

Title: Long Linear Experiment (LLX)
Contractor: Los Alamos Scientific Laboratory
Group Leader: Unspecified
DMFE Program Contact: **W. Ellis**

Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
				Fiscal Years					
Normal Operation	0	0	0	100	100	200	500	2000	2900
Device Fabrication	0	0	0	0	0	0	0	500	500
Total Operation	0	0	0	100	100	200	500	2500	3400
Equipment	0	0	0	160	0	0	100	300	560
Line Item Construction (TEC 75M)	0	0	0	0	0	0	0	19000	19000

Milestones:		
1.	Begin conceptual design	October 1978
2.	Complete conceptual design	October 1979
3.	DMFE decision point	April 1980
4.	Complete Title I preliminary design	July 1981
5.	Begin building construction	April 1982
6.	Complete building construction	April 1983
7.	Complete device assembly	October 1984
8.	Complete checkout and being plasma operation	April 1985

Summary: The Long Linear Experiment (LLX) is the next logical step in the linear theta pinch program leading to a reactor. LLX will provide dense thermonuclear plasma in high intensity magnetic fields. Objectives of the research on this device include plasma heating to about 6 keV over long plasma lengths. The primary heating mechanism will be compressive shock heating. However, end-on heating by plasma guns and lasers are also planned. At number densities of the order of 10^{17}cm^{-3} and field strengths of the order of 300 kG, confinement times of the order of 100 μsecs are anticipated even without end-stoppering. This yields an $n\tau$ of approximately 10^{13} sec cm^{-3}. End-stoppering techniques developed on Scylla IV-P will provide confinement times significantly better than this.

Title: Conceptual Studies
Contractor: Los Alamos Scientific Laboratory
Group Leader: John Marshall
DMFE Program Contact: W. Ellis

Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	Total 78-82
	Fiscal Years								
Normal Operation	150	25	60	30	0	0	0	0	30
Device Fabrication	0	0	0	0	0	0	0	0	0
Total Operation	150	25	60	30	0	0	0	0	30
Equipment	0	0	0	0	0	0	0	0	0

Milestones:

1.	Initiate study of high-beta alternatives to the Scyllac concept	July 1975 (achieved)
2.	Report to FPCC meeting on results of preliminary study	January 1976 (achieved)
3.	Continue alternatives study	

Summary: The Conceptual Studies program was initiated at LASL to examine the possibilities for new program directions in the high-beta field which are not in support of, or directly related to, the Scyllac concept. The range of the study includes the linear theta pinch, toroidal diffuse Z-pinch, fast liner flux compression, Tormac, Surmac, and reversed-field theta pinches. The studies involve considerations of reactor promise, anticipated technological and physics problems, compatibility with existing hardware, and availability of appropriate diagnostics. These studies will be terminated after new program directions at LASL, if needed, become better defined.

Technical Projects Office

Title: Tokamak Fusion Test Reactor (TFTR)
Contractor: PPPL

DMFE Program Contact: J. N. Grace

Fiscal Years
Millions

	1976	1976A	1977	1978	1979	1980	1981	1982	FY78-82 Total
Construction: (TEC $228.0)	15.0	5.5	80.0	94.4	32.7	0	0	0	127.1
Operating (Total)	0.4	0.8	10.0	15.3	10.3	20.0	23.0	25.0	93.6
Component Dev.	0.4	0.8	9.5	12.3	3.0	2.6	2.3	0	20.2
Exp. Research	0	0	0.25	1.6	2.8	5.6	6.2	10.0	26.2
Facilities Operation	0	0	0.25	1.4	4.5	11.8	14.5	15.0	47.2
Equipment	0.15	0.05	1.0	2.0	2.7	2.9	1.3	0	8.9

Milestones:

1. Order Long Lead Material (Toroidal Field Coils) 12/76
2. Order Motor-Generator-Flywheel System 12/76
3. Start Site Construction 2/77
4. Complete Tokamak System Final Design Review 8/77
5. Initiate Fabrication of Vacuum Vessel 5/78

Title: Tokamak Fusion Test Reactor (TFTR)
Contractor: PPPL
DMFE Program Contact: J. N. Grace

6.	Initiate Fabrication of Toroidal Field Coils	10/78
7.	Order Neutral Beam Systems Production Unit	4/79
8.	Delivery of first MG Set	10/79
9.	Complete TFTR Complex Construction	1/80
10.	Start Final Assembly of Tokamak	5/80
11.	Initiate Testing of Neutral Beam Line #1	7/80
12.	Complete Site Construction	11/80
13.	Hydrogen Plasma Operation	6/81

Summary:

The purposes of the TFTR Project are: (1) to demonstrate fusion energy production from the burning, on a pulsed basis, of deuterium and tritium in a magnetically confined toroidal plasma system; (2) to study the plasma physics of large tokamaks; and (3) to gain experience in the solution of engineering problems associated with large fusion systems that approach the size of planned experimental power reactors. These purposes will be satisfied by production of one to ten megajoules of thermonuclear energy (per pulse) in a deuterium-tritium tokamak with neutral beam injection under plasma conditions approximating those of an experimental fusion power reactor.

The TFTR experiment, including the required facilities, will be built at PPPL and is expected to be ready for initial operation around 1980. The principal design features are:

--2.7 m. major radius; 1.7 m. plasma diameter

--2.5 MA maximum plasma current

Title: Tokamak Fusion Test Reactor (TFTR)
Contractor: PPPL   DMFE Program Contact: J. N. Grace

--Target plasma conditions: $n\tau \sim 10^{13}$; $T_e \sim T_i \sim$ 3-4 keV

--Injected beam energy: up to 150 keV

--Water-cooled copper magnets

--50 kG centerline field

--Pulsed power supply with flywheel storage; 4500 MJ, 660 Mw

-- Capability for tritium handling and maintenance

--Shielded magnets and auxiliary systems

--Provision for adiabatic compression (c = 1.5)

--Capability for remote maintenance

The Component Development activity provides for the experimental and analytical effort necessary to develop systems and components for use in TFTR. These tasks are keyed to the design of the device and associated hardware and must be completed to assess design options or to prove out prepared designs or processes. The Experimental Research activity provides for the preparations for the experimental plasma physics testing in TFTR. The Facility Operation category provides for preparation for facility operations.

Title: Rotating Target Neutron Source-II (RTNS-II)
Contractor: LLL

DMFE Program Contact: D. J. McGoff

Fiscal Years
Millions

	1976	1976A	1977	1978	1979	1980	1981	1982	FY78-82 Total
Construction: (TEC $5.0M)	2.5	0	2.5	0	0	0	0	0	0
Operating	0*	0*	0*	1.2	0	0	0	0	1.2
Equipment	0*	0*	0*	0.11	0	0	0	0	0.11

Milestones: 1. Begin operation 1978

Summary:

The RTNS is a 14 MeV neutron source in which a deuterium beam is accelerated to react with a solid rotating target, the surface of which is titanium tritide. The resulting flux of 14 MeV neutrons has a source strength of approximately 2 x 10^{13}n/cm^2/sec. The size of the spot is about 1 cm in diameter. The facility will consist of two accelerators and two rotating targets in separate radiation cells. Samples will be irradiated for surface studies and microstructural studies to determine the effect of 14 MeV neutrons.

For separate line items, prototype development, construction, and initial operation are the responsibility of the DMFE Technical Projects Office (TPO). This data sheet shows funding through FY 78 for those activities. Beginning with FY 79, its operation becomes the responsibility of DMFE's Development and Technology Program and funds for operation of facility are included in their data sheet.

* Carried under D&T Funding Budget for FY 76-77 as follows:

	1976	1976A	1977
Operating	0.470	0.165	0.5
Equipment	0.04	0.01	0.04

Title: Intense Neutron Source (INS)
Contractor: LASL

DMFE Program Contact: D. J. McGoff

Fiscal Years
Millions

	1976	1976A	1977	1978	1979	1980	1981	1982	FY78-82 Total
Construction: (TEC $25.4M)	.100	0	14.4	10.9	0	0	0	0	10.9
Operating	0*	0*	0*	1.5	1.7	2.0	2.0	0	7.2
Equipment	0*	0*	0*	0.19	0.8	0.1	0.1	0	1.19

Milestones: 1. Begin operation 1981

Summary:

The INS is a 14 MeV neutron source in which a tritium beam is accelerated to react with a supersonic deuterium gas target. The resulting flux of 14 MeV neutrons has a source strength of approximately $1 \times 10^{14} n/cm^2/sec$. The DT reaction occurs in about 1 cm^3 of volume which radiates neutrons in all directions. Specimens are placed circumferentially around the nozzle containing the reaction. The facility will consist of two accelerators and two gas targets in separate radiation cells. Samples will be irradiated for surface and microstructural studies, as well as for post irradiation and in-situ mechanical properties studies.

For separate line items, prototype development, construction, and initial operation are the responsibility of the DMFE Technical Projects Office (TPO). This data sheet shows funding through FY 81 for those activities. Beginning with FY 82 INS operation becomes the responsibility of DMFE's Development and Technology Program and funds for operation of facility are included in their data sheet.

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*Carried under D&T budget for FY 76-77 as follows:

	1976	1976A	1977
Operating	0.8	.215	.75
Equipment	.13	.03	.1

Development and Technology Program

Magnetic Systems

Title: Superconducting Magnets
Contractors: BCL, BNL, LLL, ORNL, GA, NBS, universities and industry

DMFE Program contact: E. J. Ziurys

Fiscal Years
Millions

Budget:	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
Operating:	5.20	1.40	13.04	11.56	13.41	17.20	19.84	21.20	83.21
MDF:	-	-	2.41	4.84	7.59	5.80	5.26	8.00	31.49
Equipment:	1.01	0.27	1.60	2.20	4.35	4.90	6.95	7.95	26.35

Milestones: Tokamak Superconducting Magnet Development

A. Large Coil Project

1.	Industry to complete conceptual design of EPR-I magnet	Oct 1976
2.	Select Large Coil Test configuration	Oct 1976
3.	Contracts to industry are let to design and fabricate superconducting Large Coils (about 3m bore)	Feb 1977
4.	Select test site and contractor to test Large Coils	Apr 1977
5.	Complete design of Large Coils	Mar 1978
6.	Complete installation of Large Coil test equipment	Sept 1979
7.	Complete fabrication of Large Coils	Sept 1979
8.	Complete Single Coil test	Mar 1980
9.	Start test of Compact Torus	Sept 1980

B. Technology Development

1.	Complete hollow conductor (MIT) analysis	July 1976
2.	Complete design of Large Coil segments	Nov 1977
3.	Complete segment coil test facility analysis	Feb 1978
4.	Complete test on cooling concepts	July 1978

B. Technology Development (cont'd)

5.	Complete insulation studies	Dec 1978
6.	Complete NbTi impurity study	Dec 1978
7.	Complete conductor joining techniques	Dec 1978
8.	Complete evaluation of coil fabrication methods	Jan 1979
9.	Complete coil segment tests	Mar 1979
10.	Complete fabrication development and test of coil sector	Mar 1979
11.	Test intermediate size coils and evaluate pulse and AC effects	July 1980

C. TNS (The Next Step) Reactor Superconducting Magnet Development

1.	Start conceptual design of TNS coils	Dec 1976
2.	Decision to build TNS magnet prototype	Mar 1978
3.	Start construction of TNS prototype	Oct 1979
4.	Complete ordering of Long Lead Items and materials, including superconductor for single coil	Sept 1980
5.	Complete single coil fabrication (∿6m bore)	June 1981
6.	Complete single coil prototype test	Feb 1982

Mirror Superconducting Magnet Development

A. MX, Subsize FERF and FERF

1.	Decision to build MX	July 1976
2.	Title I begins for MX	Oct 1977
3.	Complete MX superconductor development	Sept 1978
4.	Complete first phase Nb_3Sn development	Sept 1978
5.	Complete MX magnet design	Nov 1978
6.	Complete subsize FERF magnet design	Oct 1981
7.	Complete second phase Nb_3Sn development	Oct 1981
8.	Decision to build FERF	Mar 1982

B. ETR

1.	Start conceptual design	June 1979
2.	Complete scoping study	Feb 1982
3.	Decision to build	May 1982
4.	Title I begins	Oct 1983
5.	Start fabrication of coils	July 1985
6.	Complete installation of magnet coils	July 1988
7.	Start tests	July 1989

C. High Field Test Facility

1.	Start design of High Field Test Facility (HFTF) coils	Oct 1976
2.	Complete design of HFTF coils	Sept 1977
3.	Order materials	Oct 1978
4.	Complete fabrication of HFTF coils	Nov 1979
5.	Complete fabrication of HFTF component parts	Jan 1980
6.	Complete installation of HFTF	June 1980
7.	HFTF in operation	Sept 1980

Advanced Technology Development

1.	Complete survey of existing superconducting magnet protection systems and failures	Nov 1975
2.	Complete dynamic interaction of pulsed poloidal fields and toroidal coils model tests	Sept 1976
3.	Complete computer code to calculate the vibrations in the toroidal field magnets due to poloidal field coils	Jan 1977
4.	Complete lateral stability and dynamic interaction of toroidal and poloidal magnets in proposed EPR-I designs	Sept 1977
5.	Complete technical and economic evaluation of hydrostatic extrusion process as applied to NbTi and Nb_3Sn superconductor fabrication	Oct 1977

6. Complete transfer of hydrostatic extrusion process to candidate commercial vendors through the release of all engineering data and on-site assistance	Oct 1977
7. Complete magnet safety report formats	
a. Low radioactivity inventory systems	Oct 1978
b. High radioactivity inventory systems	Sept 1980
8. Complete fault trees for most likely accidents - Large Fusion Magnets	Sept 1980

Summary:

The Magnetics planning element consists of three major parts: the NbTi Tokamak magnet development program at ORNL, the Nb_3Sn mirror magnet development program at LLL, and an advanced technology development program directed from DMFE.

The effort to support the Tokamak concept is directed at providing the large toroidal field magnets that will be necessary to confine plasmas in devices such as the Prototype Experimental Power Reactor which is projected to operate in the mid-1980's, Experimental Power Reactor in the early 1990's, and a Demonstration Fusion Power Reactor which is projected for a test in the late 1990's. Tokamak reactor studies project the need for "D" shaped niobium-titanium and possibly high field niobium-tin superconducting magnets with inside dimensions of about 20 by 15 meters, which, when arranged in toroidal geometry, will produce a central field of 4 to 6 Tesla and a peak field between 8 and 12 Tesla. The program is comprised of a series of steps of fabricating and testing of magnets of increasing size to confirm design, fabrication, and operational predictions. The first of these steps, a Large Coil Project, has been instituted to culminate in a major test assembly in 1979-1980.

The program to support the mirror concept proceeds with a planned approach similar to the Tokamak plan. The magnets are of a much more complicated Yin-Yang geometry and the superconductor development stresses niobium-tin instead of niobium-titanium because of the higher field strengths needed. The mirror concept uses the Yin-Yang geometry, which encloses a volume approximated by a sphere of 8 to 10 meters in diameter. The superconducting windings would be niobium-tin and produce a vacuum central field of about 5 Tesla, a field in the mirror region of 10 Tesla and a peak field of about 12 Tesla. Some of the mirror type devices projected for construction are the Mirror Experiment with niobium-titanium conductor in the early 1980's, Engineering Test Reactor in the late 1980's, subsize FERF in the early 1980's, and a FERF in late 1980's. The LLL plan includes multifilamentary niobium-tin superconductor wire development program. Because such large-volume, high-field magnets have never been built, the program includes a vigorous effort for development of mass production of consistent, well-characterized superconducting wire, as well as magnet system design, fabrication, and testing.

The Advanced Technology Development program covers developmental efforts of advanced superconductor fabrication methods, cryogenics, structural materials, advanced superconducting materials, magnet vibration, and stability and safety of superconducting magnets.

Title: Base program and unselected MDF
Contractors: BCL, BNL, GA, LLL, NBS, ORNL,
Universities, and industry

DMFE Program contact:
E. J. Ziurys

Fiscal Years
Millions

Budget:[1/]	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
Operating	4.55	1.11	10.75	6.00	8.00	14.8	17.29	18.53	64.62
MDF (Unselected)	.0	.0	.0	.20	.50	3.50	5.00	8.00	17.20
Equipment	1.01	.27	1.17	.70	4.35	4.75	6.80	7.8	24.4

Milestones:

1.	Complete survey of existing superconducting magnet protective systems.	Nov. 1975 (achieved)
2.	Complete studies on lateral stability and dynamic interaction of toroidal and poloidal magnets in proposed EPR designs.	Sept. 1977
3.	Complete technical and economic evaluation of hydrostatic extrusion processes as applied to NbTi and Nb_3Sn superconductor fabrication.	Oct. 1977
4.	Complete design of a large coil segment.	Nov. 1977
5.	Complete first phase of Nb_3Sn multifilamentary conductor development.	Sept. 1978
6.	Complete Large Coil segment tests.	Mar. 1979
7.	Complete second phase of Nb_3Sn multifilamentary conductor development.	Oct 1981
8.	Complete TNS single coil prototype test.	Feb. 1982

[1/] The budget data for this subelement are included in Superconducting Magnets.

Summary:

The Base Program is designed to cover a number of activities required for the general advancement of superconductivity and for specific superconducting magnet systems development such as the Mirror Experiment, Compact Torus, Prototype Experimental Power Reactor, Fusion Engineering Research Facility, and Experimental Power Reactor. These activities include the development of basic superconducting technology, NbTi, and Nb_3Sn multifilamentary superconductors, advanced superconducting materials and superconductor fabrication methods, cryogenics, and structural materials. Also in the Base Program, studies are performed which include magnet vibration and stability, safety of large superconducting magnets, superconductor and magnet systems design, and magnet fabrication and testing.

Title: Large Coil Project (MDF)
Contractor: Oak Ridge National Laboratory
Group Leader: P. N. Haubenreich

DMFE Program Contact:
E. J. Ziurys

Fiscal Years
Millions

Budget: [1]	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
Operating*:	0.573	0.235	2.286	5.562	5.410	2.30	2.35	2.40	18.022
MDF:	0	0	2.214	4.438	6.290	1.60	0	0	12.328
Total Operating:	0.573	0.235	4.500	10.000	11.700	3.90	2.35	2.40	30.350
Equipment:	0	0	0	1.50	0	0.10	0.10	0.10	1.8

* Most of the dollars through FY 1979 will be spent in industry on design and fabrication of large coils.

Milestones:

1.	Industry to complete conceptual design of EPR magnet	Oct 1976
2.	Contracts to industry are let to design and fabricate superconducting Large Coils (about 3m bore)	Feb 1977
3.	Design of Large Coils completed	Mar 1978
4.	Fabrication of Large Coils completed	Sept 1979
5.	Complete Large Single Coil tests	Mar 1980
6.	Start tests with Compact Torus	Sept 1980

Summary:

The Large Coil Program is designed to evolve large superconducting coil designs (about 3m bore) that would provide information for the design of even larger coils for The Next Step (TNS) and the Engineering Power Tokamak type Reactors (EPR).

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[1] The budget data for this subelement are included in Superconducting Magnets.

Program will provide conceptual designs of the EPR coils by the three different industrial firms. The information gained through these conceptual designs will be used to prepare specifications for the design and fabrication of large coils in industry. Coils obtained from industry will be tested in a toroidal array to determine their performance and behavior. The results of these tests should provide basis for design of TNS and EPR size superconducting coils.

Title: High Field Test Facility (MDF)
Contractor: Lawrence Livermore Laboratory
Group Leader: D. N. Cornish

DMFE Program Contact:
E. J. Ziurys

Fiscal Years
Millions

Budget: [1]	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
Operating:	0.075	0.050	0	0	0	0.10	0.20	0.27	0.57
MDF:	0	0	0.20	0.20	0.80	0.70	0.26	0	1.96
Total Operating:	0.075	0.050	0.20	0.20	0.80	0.80	0.46	0.27	2.53
Equipment:	0	0	0.433	0	0	0.05	0.05	0.05	0.15

Milestones:

1. Start design of High Field Test Facility (HFTF) coils	Oct 1976
2. Complete design of HFTF coils	Sept 1977
3. Complete fabrication of HFTF coils	Nov 1979
4. Complete installation of HFTF	June 1980
5. HFTF in operation	Sept 1980

Summary:

The High Field Test Facility (HFTF) is designed to provide a test bed for evaluation of multifilament Nb_3Sn superconductor performance in fields above 8T and NbTi superconductors in fields below 8T. Such a test facility is required as a next step in the development of practical superconductors for large MFE magnetic mirror devices such as FERF, ETR, and MX as well as development of superconductors for possible application in Tokamak type machines.

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[1] The budget data for this subelement are included in Superconducting Magnets

Various multifilament superconductor and coil designs will be evaluated in the environment encountered in large MFE devices. Superconductors will be wound into coils of about 0.4m bore and inserted into the HFTF for performance evaluation.

This test facility will be available also to the MFE community for evaluation of superconductors and coil designs.

Title:	Energy Storage and Transfer		DMFE Program Contact:
Contractors:	National Labs, Universities, Industry		D. S. Beard

Fiscal Years
Millions

Budget:	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
Operating:	2.20	0.45	1.90	1.9	3.3	4.5	6.0	6.0	21.7
MDF:	-	-	0.40	0.7	0.7	0.5	1.0	2.0	4.9
Equipment:	0.24	.05	0.25	0.5	0.5	0.7	0.7	1.0	3.4

Milestones:

1.	Design, fabricate, and test 300 KJ superconducting storage coil	Jan 1975 (achieved)
2.	Design, fabricate, and test a normal 5 MJ homopolar motor generator	June 1975 (achieved)
3.	Evaluate current Tokamak ohmic heating designs	Aug 1976
4.	Design, fabricate, and test commercially developed 300 KJ superconducting storage coils	Oct 1976
5.	Fabrication and testing of exploratory fast discharging (1 ms) machine (0.5 MJ) (cooperative effort with EPRI)	Mar 1977
6.	Design, fabricate, and test a 400 kJ prototype SFTR superconducting storage coil	Sept 1977
7.	Demonstrate a superconducting SFTR prototype system (1 coil)	Apr 1978
8.	Complete conceptual design of Tokamak OH system and scaled model	Sept 1979
9.	Design, fabricate, and test a superconducting fast discharge (0.03 sec) 10 MJ homopolar motor generator (cooperative effort with EPRI)	May 1980
10.	Develop and evaluate various superconductors for pulsed OH coils	June 1980
11.	Fabricate and test scaled model of OH system (10-50 MJ coil, reversible power supply system, and associated switching)	Sept 1982
12.	Initiate fabrication of EPR prototypical size OH system	Sept 1982

Summary:

The Energy Storage activity is concerned with providing the high, short pulse power that will be needed for various fusion machine subsystems. The identification of near-term needs is sometimes complicated by the time dependence of the introduction of other technologies that are under development. For example, when superconducting toroidal field coils are developed and utilized on Tokamaks, the need for large power supplies to pulse the present normal magnets is obviated. As a result, the development approach seeks to find the appropriate combination of meeting nearer-term requirements with hardware and technology that will be directly applicable to the perceived long-term requirements. As a consequence, the development approach contains elements of advanced development which, if successful, would provide options of conducting additional experiments which might not otherwise be possible, as well as a specific development program for Tokamak ohmic heating systems.

The development of magnetic and inertial energy storage systems has been identified as the two most attractive approaches at this time, and the plans call for demonstrations of prototype hardware within five years. As indicated by the milestones, a sequence of superconducting magnetic energy storage coils will be developed and fabricated. The basic modular storage coil unit is expected to be sized at 400,000 joules of energy. A demonstration of this size prototype module will provide the necessary technical and economic data to determine whether this type of energy storage system will solve the needs for pulsed high beta systems. The requirement for this type of inductive energy storage is an energy transfer time of 1 ms from the superconducting coils to a normal compression coil. The electrical current will be 25,000 amperes and a peak voltage of 60,000 volts will be reached during the transfer. The development of fast, low energy switches is a very important part of such a system.

In the inertial energy storage area, the development of both fast discharging (1-50 ms) and slow discharging (.5-2 sec) homopolar motor generators is being pursued. The milestones indicate a sequence of developing normal and superconducting homopolar machines in the size range of 5 MJ. Again, the modular unit approach is applicable to the development and successful use of these machines. They may be connected in series to form larger modules. However, the basic machine unit will probably grow in steps from 10 MJ to 1,000 MJ.

Title: Base Program and Unselected MDF
Contractors: National Labs, Universities, Industry

DMFE Program Contact:
D. S. Beard

Fiscal Years
Millions

Budget [1]	1976	1976A	1977	1978	1979	1980	1981	1982	78-82 Total
Operating	2.20	.45	1.85	1.70	3.00	4.10	5.60	5.6	20.00
MDF (Unspecified)	.00	.00	.00	.00	.00	.30	.50	2.00	2.80
Equipment	.24	.05	.20	.40	.40	.60	.60	1.00	3.00

Milestones:

1.	Design, fabricate, and test 300 KJ superconducting storage coil	Jan 1975 (achieved)
2.	Design, fabricate, and test a normal 5 MJ homopolar motor generator	June 1975 (achieved)
3.	Evaluate current Tokamak ohmic heating designs	Aug 1976
4.	Design, fabricate, and test commercially developed 300 KJ superconducting storage coils	Oct 1976
5.	Fabrication and testing of exploratory fast discharging (1 ms) machine (0.5 MJ) (cooperative effort with EPRI)	Mar 1977
6.	Design, fabricate, and test a 400 kJ prototype SFTR superconducting storage coil	Sept 1977
7.	Demonstrate a superconducting SFTR prototype system (1 coil)	Apr 1978
8.	Complete conceptual design of Tokamak OH system and scaled model	Sept 1979
9.	Develop and evaluate various superconductors for pulsed OH coils	June 1980
10.	Fabricate and test scaled model of OH system (10-50 MJ coil, reversible power supply system, and associated switching)	Sept 1982
11.	Initiate fabrication of EPR prototypical size OH system	Sept 1982

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[1] The budget data for this subelement are included in Energy Storage and Transfer.

Summary:

The Energy Storage and Transfer base program currently is concentrating on the development of the technology needed for inertial and superconducting magnetic energy storage systems.

In the inertial energy storage area, development is being concentrated on both normal and superconducting homopolar motor-generators. Significant efforts include high current brush technology, brush actuating mechanisms, rotor materials, fabrication techniques, and pulse shaping control.

The magnetic energy storage area is concentrating on the development of a 400 KJ superconducting storage coil. The coil will be charged to 25,000 amperes over several seconds and then discharged in 0.001 seconds to provide the high power and voltage required for some future fusion applications. A separate superconducting OH coil development for tokamaks is projected to build upon the pulsed superconducting coil program. An unselected MDF project is anticipated for an OH system which requires an energy storage and transfer device in conjunction with the superconducting OH coil.

The development of various types of reliable, low loss switches to operate with inertial and magnetic energy storage systems also requires significant concurrent technology development and is included in the base program.

Title: Superconducting Homopolar Motor-Generators (MDF)
Contractor: Los Alamos Scientific Laboratory
Group Leader: John Rogers

DCTR Program Contact:
D. S. Beard

Fiscal Years
Millions

Budget: [1]	1976	1976T	1977	1978	1979	1980	1981	1982	FY 78-82 Total
Operating:	(EPRI funded design)		0.05	0.2	0.3	0.4	0.4	0.4	1.70
MDF	-	-	0.4	0.7	0.7	0.2	0.5	-	2.10
Total Operating*	-	-	0.45	0.9	1.0	0.6	0.9	0.4	3.80
Equipment	-	-	.05	0.1	0.1	0.1	0.1	-	.40

* This is planned to be a jointly funded program with EPRI. Only ERDA costs estimated for the program are shown.

Milestones:

1.	Complete detailed design, supporting R&D, and fabrication drawings	Sept 1977
2.	Complete fabrication and initial testing (contractor site)	Sept 1979
3.	Complete initial performance tests (LASL facility)	May 1980
4.	Fabricate and install upgraded rotor for higher energy (30-50 MJ) and higher voltage	Sept 1981
5.	Complete testing program and evaluation	Sept 1982

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[1] The budget data for this subelement are included in Energy Storage and Transfer.

Summary:

This program is designed to develop and demonstrate the technology of superconducting homopolar motor generators for fast and slow pulsed operations. The fast pulsed machines will support future advanced high beta fusion experiments such as theta pinches and liners, and the slower pulsed machines are expected to be an important, necessary component of tokamak ohmic heating systems.

A technology demonstration fast discharge machine will have inertially stored energy of 10 MJ, an energy discharge time of 0.03 seconds with a maximum voltage and current of 770 V and 1,400 MA, respectively. This machine after testing is expected to be retrofitted in 1981 with a heavier rotor and new brushes of advanced design and then operated in a slower discharge mode. It will have stored energy of 30-50 MJ, an energy discharge time of 1-2 seconds with maximum voltages and currents in the 2.5 KV and 200 KA ranges.

Development and Technology Program

Plasma Engineering

Title: Neutral Beam Development - Base Program
Contractors: BNL, LBL, LLL, ORNL, Industry, Universities

DMFE Contacts: J. W. Beal,
H. S. Staten

	Fiscal Year Millions								
Budget:	1976	1976A	1977	1978	1979	1980	1981	1982	FY78-82 Total
Operating:	5.34	1.50	7.20	7.5	8.5	10.0	12.0	14.5	52.5
Equipment:	0.95	0.14	0.72	1.0	1.7	1.6	2.0	2.0	8.3

Milestones:

1. Install and operate twelve 50A, 20 keV sources on 2X-IIB	Sept. 1974 (achieved)
2. Install and operate ORMAK injectors #3 and #4	Jan. 1975 (achieved)
3. Operate a pulsed, 50A source at 40 keV	March 1975 (achieved)
4. Operate 1A, 15 keV, 10 msec negative ion source	May 1975 (achieved)
5. Operate 60 kV, 60A, 2 sec test and development facility	Sept. 1975 (achieved)
6. First computer control/automatic conditioning of neutral beam lines at LBL	March 1976 (achieved)
7. Operate 150 keV, 2A, 10 msec negative ion test facility	June 1976
8 Operate prototype PLT neutral beam injection system	July 1976
9. Deliver 50A, 40 keV pulsed injectors for 2X-IIB	July 1976
10. Operate 80-150 kV, 20A, 0.5 sec test and development facility	July 1976
11. Operate 150 keV, 40A, dc test and development facility	Oct. 1976
12. Deliver PLT injection systems	Oct. 1976
13. Operate 80-150 keV, 50A, 20 msec test facility	Jan. 1977
14. Define neutral beam requirements and development plans for TNS	April 1977
15. Operate 150 keV, 1A, 10 msec negative ion beam system	June 1977
16. Select TFTR injection system design	June 1977
17. Operate 200 kV, 25A, dc test and development facility	July 1977
18. Operate prototype TFTR injection system	Dec. 1978
19. Start fabrication of PEPR/ITR Neutral Beam Test and Development facility.	Jan. 1979
20. Demonstrate efficient operation of 200 keV neutral beam system	Oct. 1979
21. Initial operation of PEPR/ITR injection systems	Jan. 1981

22. Deliver TFTR injection systems	1981
23. Deliver MX injection systems	1981 - 1982
24. Deliver PEPR/ITR injection systems	1987

Summary:

The neutral beam development effort is comprised of programs at Oak Ridge National Laboratory; Lawrence Livermore and Berkeley Laboratories; and Brookhaven National Laboratory. Other development efforts are being initiated as necessary.

The ORNL Neutral Beam Development effort is one of the major DMFE programs aimed at developing neutral beam injection systems suitable for both present and forthcoming confinement devices. The effort is generally user-oriented. Recently the ORNL program has carried through an effort to increase the injection power into ORMAK from the previous 200 kW up to a total of approximately 350 kW. With the delivery of a new power supply in 1975, a significant portion of the program has been directed toward developing injectors suitable for the PLT device. On a longer time scale, a new test stand is being designed and will be available in the fall of 1976. This new facility will provide the test bed on which to develop the next generation, high voltage injectors suitable for TFTR and will pursue initial investigation toward EPR injectors. To these ends the ORNL program will pursue a broadly-based technological program aimed at developing and understanding the following points:

(1) Efficient, steady state, uniform and quiescent plasma source.
(2) Ion optical studies to obtain ion beams with low divergence and minimum particle loss.
(3) Materials and surface studies for electrodes utilized in high gradient electric fields.
(4) Heat removal from electrodes to accomplish steady-state operation.
(5) Space charge neutralization and neutralization of the ion beam.
(6) Controlling and monitoring the ion species, impurity and streaming neutral gas content of the beam.
(7) Pumping of the excess gas from the injector modules.
(8) Coupling with high gradient accelerators at the MW power level.
(9) Operating injector modules in the environment of a toroidal plasma device.

The LLL/LBL Neutral Beam Injection (NBI) program is another of the major efforts within DMFE aimed at developing neutral beam injectors suitable for use on confinement devices. The LLL/LBL program centers on two main efforts:

(1) Extending the capability in pulsed beam technology to higher energies and longer pulses, and
(2) Development of efficient 150-200 keV neutral beam systems.

For the first area of effort, a new power supply will be available in the summer of 1976 which will allow testing of injectors with maximum parameters 150 keV, 20A, 500 msec. This capability will allow development of injector modules suitable, for example, for TFTR. For the second area of effort, a new test stand facility is being designed and will be built in order to have the ability to test neutral beam production in this new high voltage (200 keV), high power (1 MW) regime. The goal of efficient neutral beam production in this energy regime will quite probably require development of negative ion beams. However, positive ions could be utilized at this energy coupled with energy recovery and positive ion recirculation. In order to carry out the program intended to meet these objectives, it will be necessary to:

(1) Continue and expand the present pulsed beam program.
(2) Test principles and subsize components for 150-200 keV neutral beams on existing test stands.
(3) Design and assemble the 200 keV test stand.
(4) Improve gas and electrical efficiency of present positive ion sources.
(5) Continue and expand the development of efficient negative ion sources.
(6) Obtain plasma and accelerator physics information required for the design of efficient neutral beam systems.
(7) Operate high through-put cryogenic vacuum systems.
(8) Design and operate reliable, high-power protective electronics.

The BNL-Negative Ion Beam program is a supporting and backup effort in the overall DMFE neutral beam programs. The BNL effort is charged primarily with developing and understanding the direct extraction negative ion source and surveying the potentialities of scaling such an ion source to the MW level for neutral beam injection systems. Two problem areas are basic to this style of ion source:

(1) Developing a reliable and reproducible source of high current negative ions, and
(2) Developing means of controlling and transporting high current density negative ion beams with strong space charge fields.

A small test facility has been built at BNL and is available to test and study negative ion sources and their behavior. This is a relatively low power facility at the present time and is used to verify the scaling laws of particular negative ion source geometries. A new test stand facility will be built in FY 1976 to accommodate 150 keV negative ion beams at the 150 kW level. In addition, this test facility will utilize a cryopumping vacuum system rather than the more conventional pumping systems presently installed on the neutral beam lines. This vacuum system will provide the first on-line test of such a pumping system and will provide data on emissivity, desorption and thermal conductivity of such a pumping system in an operating environment. This information will provide much needed support to the entire DMFE neutral beam program.

Other programs will be instituted as a research and development effort in support of the principal neutral beam efforts listed above. These efforts are small programs which could directly contribute to the efficiency and utility of ion sources, accelerators and neutralizing systems.

Programs in this activity will consider other types of ion sources for both positive and negative ions. Two questions to be addressed in this effort are efficiency of ion production and suitability of such ion sources for complete neutral beam system integration. The question of accelerators will address other acceleration mechanisms such as collective acceleration, radiofrequency acceleration and advanced electrostatic acceleration systems. In addition, research and development will be conducted toward obtaining more efficient and compatible neutralizers both of the gas cell types and the solid or vapor cell type.

Most of this work will be carried out in private industry and universities. This will help provide a much needed industrial base for the neutral beam program. In addition, university contracts will provide an educational opportunity for training of personnel in the neutral beam area.

Title: 150 keV Test Stand (MDF)
Contractor: ORNL

DMFE Contacts:
J. W. Beal
H. S. Staten

Fiscal Years
Millions

	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
MDF	2.25	0.62	-	-	-	-	-	-	-
Operating	-	0.15	1.5	1.9	2.0	1.5	1.5	1.5	8.4
Equipment	.45	0.05	0.1	0.1	0.15	0.1	0.1	0.1	0.55

Milestones:

1.	Submit proposal for 150 keV test stand	Sept 1974 (achieved)
2.	Complete review of proposal	Apr 1975 (achieved)
3.	Initiate fabrication of test stand	Apr 1975 (achieved)
4.	Begin operation of 150 keV test stand	Oct 1976
5.	Complete tests of first generation 150 keV injector module	Oct 1977
6.	Complete testing of prototype TFTR ion source module	Oct 1978
7.	Start conversion to Advanced Test Facility	Oct 1980

Summary:

The principal objective of the 150 keV Neutral Beam Test and Development facility is to provide a test facility for the development of neutral beam injectors in the 150 keV, 50A, long pulse ion beam range. Such a test stand will provide nominal 1 MW D^0 beam injection modules needed to demonstrate D-T burning in the TFTR. The beam energy and power levels of this test stand are also necessary steps in the development of beam injectors for a future Experimental Power Reactor.

The test stand is basically two subsystems: a vacuum pumping system and a power supply system. These basic subsystems are then arranged so as to simulate a beam line injection system. This arrangement will mock-up the gas handling requirements, beam dump systems, power-handling requirements, diagnostics and controls. This test facility has been designed so that the basic vacuum and electrical modules can be arranged in several configurations so as to provide a wide range of experimental operating conditions.

It is expected that the electrical portion of this test stand be up-graded and then shared with the Advanced Test Facility. This conversion is scheduled to take place in FY 1980.

DMFE Contacts:
J. W. Beal
H. S. Staten

Title: 200 keV High Voltage Test Stand (MDF)
Contractor: LLL

Fiscal Years
Millions

Budget:	1976	1976T	1977	1978	1979	1980	1981	1982	FY 78-82 Total
MDF	0.80	0.55	1.8	-	-	-	-	2.0	2.00
Operating	-	-	0.5	1.5	2.0	2.3	2.5	3.0	11.30
Equipment	0.82	.17	0.3	0.1	0.15	0.1	.2	0.7	1.25

Milestones:

1.	Submit proposal for 200 keV HVTS	Sept. 1974 (achieved)
2.	Complete review of proposal	Jan 1975 (achieved)
3.	Initiate fabrication of HVTS	Feb 1975 (achieved)
4.	Begin operation of HVTS	July 1977
5.	Complete tests of first generation 200 keV injection module	July 1979
6.	Demonstrate efficient operation of 200 keV neutral beam system	Oct 1979
7.	Initiate up-grade for test and development of EPR beam system	Jun 1982

Summary:

The primary objective of the 200 keV High Voltage Test Stand program at LLL is to provide for the development of 150-200 keV injector systems with improved performance characteristics (primarily efficiency). Such efficient beam systems could be used on TFTR and are required on future fusion reactor devices.

The HVTS has two basic operating modes:

1. 25A, up to 200 kV, dc.
2. 100A, up to 100 kV, several sec.

Also the power supplies are electrically isolated to permit operation with either positive or negative ions.

The vacuum pumping system associated with the HVTS is a cryocondensation system operating at 4.2°K. This pumping system will give the required pumping speed and gas through-put to maintain proper vacuum conditions throughout the beam line.

The HVTS is located in a shielded area. This will permit full-power, full duty-cycle operation with high energy deuterons in the resultant neutron environment.

It is anticipated that the HVTS will be upgraded beginning in FY 1982 in order to begin development of EPR neutral beam systems.

Title: TFTR Prototype (MDF)
Contractor: Undesignated
DMFE Contact: J. W. Beal

	Fiscal Year Millions								
Budget:	1976	1976A	1977	1978	1979	1980	1981	1982	FY78-82 Total
MDF:	-	-	2.00	3.5	-	-	-	-	3.5
Operating:	0	0.35	1.00	0.6	1.5	0.8	-	-	2.9
Equipment:	-	-	0.55	0.7	0.5	0.2	-	-	1.4

Milestones:

1. Complete conceptual designs of TFTR beam injection system Sept. 1975 (achieved)
2. Initiate detailed design of prototype July 1976
3. Complete detailed design of prototype June 1977
4. Select TFTR injection system design and initiate fabrication June 1977
5. Begin operation of prototype Jan. 1979
6. Complete testing and evaluation of prototype April 1980

Summary:

The Tokamak Fusion Test Reactor (TFTR) under construction at the Princeton Plasma Physics Laboratory is the largest and most complex fusion yet undertaken by DMFE. The neutral beam injection systems required for heating the TFTR plasma are considerably beyond the present state of development. In order to decrease the risk associated with the TFTR beam systems, a prototype beam injection system will be built and tested before the design of the final, production units is fixed. The prototype, therefore, represents the next step beyond the ongoing high-energy beam development effort.

The prototype beam injection system will consist of an assembly of beam line components which function to produce deuterium ions, accelerate the ions to high energy, and neutralize the ions to produce energetic neutral particles. The system will provide the necessary vacuum and gas handling systems to prevent excessive leakage of thermal gas into the torus. Furthermore, a prototype electrical, diagnostic and control system will be used to power and operate the complete beam injection system.

Title: Advanced Beam Test Facility (ABTF) (MDF)
Contractor: Undesignated
DMFE Contact: J. W. Beal

Budget:	Fiscal Year Millions								
	1976	1976A	1977	1978	1979	1980	1981	1982	FY78-82 Total
MDF:	-	-	-	-	3.0	2.0	2.0	-	7.0
Operating:	-	-	-	0.5	0.5	1.5	2.5	3.0	8.0
Equipment:	-	-	-	0.2	2.0	2.0	0.7	0.2	5.1

Milestones:		
	1. Define neutral beam requirements and development plans for TNS	April 1977
	2. Prepare design and proposal for ABTF	April 1978
	3. Complete review of ABTF design and proposal	July 1978
	4. Initiate construction of ABTF	Oct. 1978
	5. Complete construction and begin operation of ABTF	April 1981

Summary:

Present estimates indicate that neutral beam systems for The Next Step (TNS) will be in the 300-400 keV range. Total injected neutral power for TNS will be of the order of 50-100 MW. Neutral beam systems in this parameter regime will represent the next major step in neutral beam development.

The Advanced Beam Test Facility (ABTF) will provide the test bed to carry out this major extrapolation. In this 300-400 keV energy range, efficiency will be of primary importance. Therefore, this facility will be capable of operating with negative ions, direct energy converters, ion recirculators, and/or other efficiency improving systems. Also, this facility will be fully shielded to permit full power, high duty-cycle operation of deuterium beams.

Title: Alternate Heating
Contractors: LASL, ORNL, PPPL, Industry

DMFE Program Contact: H. S. Staten

Budget:	Fiscal Year Millions								
	1976	1976A	1977	1978	1979	1980	1981	1982	FY78-82 Total
Operating:	1.492	0.450	3.50	2.80	3.5	3.5	4.5	5.0	19.30
Equipment:	0.070	0.025	0.23	0.75	1.0	1.0	2.0	1.0	5.75

Milestones:

1.	Develop and evaluate 125 kV spark gap switches for STP	Jan. 1975 (achieved)
2.	Install and operate 30 kW microwave system on EBT	April 1975 (achieved)
3.	Install and operate 200 kW LHR rf system on ATC	Sept. 1975 (achieved)
4.	Test wave guide coupling on H-1 and ATC	Jan. 1976 (achieved)
5.	Complete conceptual design of a 200 kW, 120 GHz microwave system	June 1976
6.	Define rf heating system technology requirements for TNS	Oct. 1976
7.	Fabricate Marshall coil	Nov. 1976
8.	Complete design of multi-megawatt LHR and ICRH rf system for PDX and PLT	Jan. 1977
9.	Install and operate 100 kW LHR rf system on ORMAK	June 1977
10.	Develop and test components for SFTR 200 kV implosion heating circuit	June 1977
11.	Evaluate power crowbar system	Sept. 1977
12.	Complete design of rf system for ISX	Oct. 1977
13.	Operate prototype 25 GHz microwave source for EBT-S	Oct. 1977
14.	Install and operate 2-5 MW ICRH rf system on PLT	1978
15.	Install and operate 2-5 MW LHR rf system on PLT	1978
16.	Install and operate rf system on ISX	1979
17.	Complete rf heating system preliminary design for TNS	1980
18.	Install and operate high power microwave system on EBT-II	1980

Summary:

The Alternate Heating activity presently includes radiofrequency heating,microwave heating and shock heating technology. The radiofrequency heating efforts are underway at PPPL and ORNL; the microwave technology program is carried out at ORNL; the shock heating program is carried out at LASL.

The PPPL activity covers the development of techniques for radiofrequency heating of plasmas. Radiofrequency heating is a major alternative or supplement to neutral beam heating. The PPPL development work is being carried out on rf heating at the ion cyclotron frequency (ICF) and the lower hybrid frequency (LHF). The advantage of ICF heating is that large blocks of power are available from commercially available power tubes. The theory is fairly well understood and tests on ST indicate this heating technique will scale to a reactor. The disadvantage is that antenna are probably required inside the vacuum wall. Work is, however, planned to develop loaded waveguide coupling techniques that may overcome this disadvantage. The engineering advantages of working at the LHF are two-fold. First, there is a significant amount of power available from commercial tubes in the frequency range that is required for fusion research devices and reactors. Second, rf power at this frequency can, in general, be transmitted through the vacuum vessel wall by waveguides rather than complicated coupling structures. This avoids the high-voltage insulator problem with antenna connections at the vacuum wall. To these ends the PPPL program will follow a technological development program aimed at these following points: (1) construct and operate moderate rf heating system; (2) develop efficient and effective rf coupling structure, demonstrate viability and scaling of rf heating system; and (3) design, construct and operate high power rf heating systems over a range of frequencies.

The ORNL rf activity applies to the development of techniques for radiofrequency heating of torodial plasma devices. The ORNL development work is specifically directed at rf heating on ORMAK at the lower hybrid frequency (LHF). In addition, conceptual design work and preliminary studies will be carried out relating to rf systems operating at the ion cyclotron frequency and also the Alfven frequency. Such systems will be used on the ISX device.

With these objectives the ORNL program will pursue a technological development program aimed at the following points: (1) construct and operate moderate rf heating systems; (2) develop efficient and effective rf coupling structures; and (3) design high-power rf heating systems over a range of frequencies.

The ORNL millimeter wave effort encompasses the development of multi-kilowatt, millimeter microwave power sources and coupling circuits. This effort is to develop heating mechanisms near the electron cyclotron frequency and is currently being tested on the EBT device. In order to provide efficient energy transfer of the microwave power to the plasma, the microwave frequency is chosen to resonate with the electron gyrofrequency. Although microwave heating is primarily coupled to the electron portion of the plasma population, collisional ion heating does result for a toroidal geometry,and stability then depends strongly upon the proper control of the electrons. Microwave heating can, therefore, be a heating method either in the main or as an adjunct to another heating mechanism. This project at ORNL utilizes subcontracted private industry for the development of specific microwave sources. The ORNL microwave development program, in addition to the above, will demonstrate the following: (1) corroborate microwave heating results of other toroidal devices; (2) demonstrate compact and compatible coupling schemes, possibly wave guides or horns; (3) demonstrate ease of control with regards to both frequency response and dynamic range; and (4) demonstrate tokamak applications for bulk versus concentrated heating applications.

The LASL activity covers the development of techniques and components associated with shock heating of plasmas. Such techniques are the principle methods of plasma heating in pinch devices. The next generation theta-pinch or similar high-beta experiments will require implosion heating fields with faster rise-times and compression fields which can be sustained for longer times.

In order to meet these two requirements of fast rise-time and long decay time, a system employing two separate coils is envisioned. The implosion heating coil is of a unique design developed by John Marshall; the compression coil is a multi-turn solenoid. Materials such as ceramics which can withstand both the high neutron flux and plasma particle flux must be developed if these systems are to be successful. One of the more promising areas of development is in the area of castable ceramics. If successful, the development of such materials would be very important to other MFE ceramic needs in addition to the Marshall coil.

In addition, this program will continue to pursue a long-term development program to produce low cost capacitors. Furthermore, this program will pursue the development of high voltage capacitors, low voltage spark gaps, high voltage Marx generators and trigger circuits, and other associated components. These components will have utility in many areas of MFE in addition to implosion heating and compression field applications.

Title: Direct Energy Conversion
Contractors: LLL
DMFE Program Contact: H. S. Cullingford

Budget:	Fiscal Year Millions 1976	1976A	1977	1978	1979	1980	1981	1982	FY78-82 Total
Operating:	0.200	0.05	0.40	0.50	0.8	0.8	1.0	1.0	4.10
Equipment:	0.015	0.005	0.08	0.05	0.2	0.3	0.5	0.5	1.55

Milestones:

1.	Operate multi-stage periodic focussing direct converter at predicted efficiency of about 85%	July 1974 (achieved)
2.	Operate simple, two-stage direct converter at predicted efficiency of about 65%	Jan. 1975 (achieved)
3.	Operate direct converter in conjunction with 15 keV, 4 kW ion beam	Jan. 1976 (achieved)
4.	Design beam-line direct converter for 120 keV beams at 5 kw/cm^2	Oct. 1976
5.	Operate direct converter in conjunction with 120 keV, 1 MW ion beam	June 1977
6.	Define beam-line direct converter requirements for TNS	Oct. 1977
7.	Demonstrate improved efficiency of neutral beam system using direct converter	June 1978
8.	Operate plasma direct converter on mirror device (BB-II)	Oct. 1978
9.	Complete design of a plasma direct converter for MX	Oct. 1980
10.	Deliver MX beam-line converter	June 1981
11.	Deliver MX plasma direct converter	June 1982

Summary:

The principles of direct energy conversion have been demonstrated in laboratory experiments at LLL, and the effort is now turning to the practical development for both near-term and long-term applications. Three applications for direct conversion have been identified:

1. Recovery of the energy of un-neutralized energetic ions from neutral beam systems and thus make neutral beam systems more efficient and achieve higher energies, produce less waste heat and improve in charged particle dump.
2. Recovery of the energy of plasma fuel ions which leave the plasma in a fusion reactor.
3. Recovery of the energy of fusion products (e.g. He^{++}) in the exhaust of a fusion reactor.

All three of these applications will increase the operating efficiency of the fusion reactor system. Hence, a direct converter can be viewed as a power amplifier/beam dump/ion diverter. For a mirror fusion reactor, efficient and economical direct energy converters are virtually a necessity. For tokamaks or Θ-pinch concepts, direct conversion would reduce at least the power requirements and thus would reduce costs.

The near-term applications include: (a) beam-line converters at neutral beam test stands, e.g. LLL/LBL; and (b) plasma direct converters at existing fusion devices, e.g. BB-II. The direct converter performance with these near-term applications will provide the basis for long-term development including TFTR and MX applications. The long term application is aimed at fusion reactors with conversion systems. The direct conversion system will be coupled with the thermal conversion system to reduce power losses further.

The program at LLL has developed methods to simulate direct energy conversion for plasma leakage and for ion beams. A facility is available which embodies the basic elements of the direct converter. These elements include the magnetic expander which guides the leaking plasma or ions to the separator and collector; a magnetic or electrostatic separator which separates the electrons from the plasma ions; and finally the electrostatic decelerator - collector. This test facility will be used to operate and test various decelerator - collector units having anywhere from 2 to 22 stages. Leaking plasma or ion beams will be simulated by appropriate ion sources in order to test the relevant direct conversion concepts. A computer simulation code will be used to design and predict the operation of the various direct converter assemblies.

To become practical, direct converters must hold high voltages between irregularly shaped electrodes and which contain small grid wires. In addition the electrodes will intercept power densities on the order of 2-5 kW/cm^2. Therefore, a part of the ongoing effort will be to develop electrode-insulator combinations which would be usable in a reactor environment.

Title: Vacuum Component Development
Contractors: BNL, LLL, ORNL, Industry

DMFE Program Contact: H. S. Cullingford

	Fiscal Year Millions								
Budget:	1976	1976A	1977	1978	1979	1980	1981	1982	FY78-82 Total
Operating:	0.03	0	0.50	0.70	1.2	1.3	1.3	1.5	6.00
Equipment:	0	0	0.07	0.08	0.3	0.3	0.3	0.3	1.28

Milestones:

1.	Operate 1.5×10^5 ℓ/sec cryocondensation pump	Jan. 1976 (achieved)
2.	Operate 10^5 ℓ/sec cryocondensation pump on beam line (BNL)	June 1976 (achieved)
3.	Define vacuum pumping requirements and development plan for TNS	April 1977
4.	Provide basic design data for cryocondensation and cryosorption vacuum systems	Oct. 1977
5.	Construct large scale cryocondensing vacuum system on neutral beam test facility (LLL)	Oct. 1977
6.	Test operation of titanium bulk getter pump	Jan. 1978
7.	Complete testing of cryogenic vacuum systems in radiation environment	June 1978
8.	Operate large scale cryocondensing vacuum system on neutral beam system	March 1978
9.	Test cryogenic vacuum systems in radiation environment	June 1978
10.	Operate large scale cryotrapping vacuum system	Oct. 1978
11.	Assess vacuum technology for tokamak DEMO	June 1979
12.	Complete definition of MX vacuum system design data requirements	June 1979
13.	Simulate and operate TNS vacuum pumping system	Oct. 1979
14.	Complete conceptual design of a PEPR/ITR vacuum system	Nov. 1979
15.	Test small scale steady-state pumping vacuum system	Jan. 1980
16.	Operate vacuum system module for PEPR/ITR	1982

Summary:

There are a number of areas of investigation and development which must be pursued to provide the vacuum technology demanded by near- and long-range fusion device experiments. One of the most critical near-term requirements is the development of vacuum systems capable of pumping thermal gas loads on the order of 100 torr-litres/sec of hydrogen isotopes at pressures of 10^{-5} to 10^{-4} torr. Gas loads in this regime are encountered in next generation neutral beam injection systems. This pumping must be done in a very limited space to accomodate access through magnets and beam divergence characteristics. Furthermore, under steady-state conditions the energetic beam eventually converts to thermal gas and must be pumped at a rate that provides densities tolerable to the plasma.

Additional pumping problems that must be considered for the reacting plasmas are the helium gas load due to alpha particle production and irradiation of the pumping surfaces. There are a limited number of methods for pumping helium and the attendant hydrogen load will compete with all these methods for capacity.

Conventional pumping techniques such as diffusion pumps, turbomolecular or other methods of appendage pumping will not suffice due to space limitations and the inherent impedence to the gas flow. From this it is clear that the development effort should be focussed on utilizing wall pumping techniques such as cryocondensation, cryotrapping, cryosorption, and cryogettering to these very high gas load conditions. This program will investige these vacuum pumping techniques and will develop the basic design data, capabilities, and limitations of each of them. Development and testing of other vacuum hardware (valves, flanges, seals, gauges, etc.) will be executed to support the vacuum system design as needed.

This program will complement the development of TFTR injection systems and EPR system studies as well as other reactor system designs. It will meet the vacuum component needs for steady-state and pulsed operations.

Title: Plasma Maintenance and Control
Contractors: ORNL, Universities, other undesignated

DMFE Program Contacts: H. S. Cullingford
J. W. Beal

Budget:	Fiscal Year Millions								
	1976	1976A	1977	1978	1979	1980	1981	1982	FY78-82 Total
Operating:	0	0.040	1.30	1.50	2.0	2.3	2.5	3.0	11.30
Equipment:	0	0.025	0.10	0.12	0.5	0.5	0.7	0.8	2.62

Milestones:

1.	Test first generation pellet fueling device on ORMAK	Sept. 1975 (achieved)
2.	Test prototype pellet injector device on ORMAK	Jan. 1976 (achieved)
3.	Initiate laser-pellet acceleration experiments	June 1977
4.	Define diverter requirements and development plan for TNS	Oct. 1977
5.	Demonstrate rotating mechanical pellet accelerator	Oct. 1977
6.	Establish limits for electrostatic pellet acceleration	Oct. 1977
7.	Define fueling requirements and development plan for TNS	Oct. 1977
8.	Test pellet injector device on PLT or ISX or ORMAK-UG	June 1978
9.	Test pellet injector on PDX or Doublet-III	Jan. 1979
10.	Assess plasma maintenance and control technology for tokamak DEMO	June 1979
11.	Simulate and test TNS plasma maintenance and control system	June 1980
12.	Test advanced fueling on Doublet-III	Oct. 1981
13.	Complete assessment of gas blanket fueling techniques	Jan. 1982
14.	Test pellet injector system on TFTR	Oct. 1982
15.	Complete conceptual design of diverter/fueling system for PEPR/ITR	1982

Summary:

If a tokamak fusion power reactor is to be operated for times greater than a confinement time, it will be necessary to refuel the reactor while it is operating. Because only a small fraction of the fuel will react before it is lost, methods are required to divert and collect these non-reacting plasma ions as well as fusion reaction products. This program of Plasma Maintenance and Control will investigate various refueling techniques and diverter techniques as required. The objective of the program is to enhance fusion power amplification in tokamak plasmas with sufficiently long burn times and low power requirements for the fueling device. The length of the burn time will be affected by the impurity buildup in plasma and the axial current sustenance.

The principle method currently under investigation for plasma refueling is through the use of solid pellets. Present efforts are directed toward an understanding of pellet formation and acceleration techniques. Acceleration techniques include the gas dynamic or jet technique, rotating mechanical systems, laser accelerating systems, and electrostatic accelerators. These techniques will be studied using prototype hardware to determine the operating characteristics, capabilities, and limitations associated with each.

Also, it is necessary to understand where the fuel is deposited within the plasma. This requires a knowledge of the pellet ablation rate versus pellet speed. Prototype pellet injection systems will be installed on appropriate fusion device experiments in order to determine the detailed fueling mechanisms. Other fueling approaches will be pursued as alternative techniques.

If diverters are required for fusion devices, they will place severe requirements on the particle collection devices and vacuum pumping devices for such a system. Moreover, these systems will be required to operate in a high neutron flux environment. Conceptual designs for such systems will be completed and small scale tests of such systems will be performed as necessary.

Development and Technology Program

Fusion Reactor Materials

Title: Alloy Development for Irradiation Performance
Contractors: HEDL, LASL, LLL, ORNL, PNL

DMFE Program Contact: T. C. Reuther

Fiscal Years
Millions

Budget	1976	1976T	1977	1978	1979	1980	1981	1982	FY78-82 Total
Operating	1.39	0.36	2.96	5.8	6.8	8.7	11.0	13.0	45.3
Equipment	0.28	0.03	0.17	0.33	0.9	1.0	1.2	1.3	4.73

Milestones:

1. Establish Task Group on First Wall/Structural Alloy Development and Irradiation.. August 1976
2. Establish preliminary target goals to meet the materials requirements of commercial fusion power................................ March 1977
3. Complete alloy development to meet the materials requirements of commercial fusion power.. 1993
4. Alloy Development Milestones detailed in the text of the 5 Year Program Plan
   - Path A: Austenitic Alloys
   - Path B: High Strength - High Temperature Fe-Cr-Ni Alloys
   - Path C: Reactive/Refractory Metals
   - Path D: Special and Innovative Materials Concepts

Summary:

Included in this technical area is the alloy development for the first wall and structural parts of a fusion reactor. These components are those that are highly irradiated and difficult to replace.

(sputtering and blistering); outgassing and desorption of surfaces with photon and electron bombardment; surface interactions with high energy neutrons; surface interactions with gaseous and self ions; chemical interactions at surfaces; multi-beam testing to simulate plasma-surface interactions; and surface experiments in ISX.

Title: Plasma-Materials Interaction
Contractors: ANL, GA, ORNL, PNL, Sandia,
Universities

DMFE Program Contact: C. R. Finfgeld

Budget	1976	1976T	1977	1978	1979	1980	1981	1982	FY78-82 Total
	Fiscal Years Millions								
Operating	1.63	0.39	2.05	2.8	3.6	4.5	5.0	5.0	20.9
Equipment	0.41	0.08	0.37	0.43	0.5	0.5	0.6	0.6	2.63

Milestones:

1. Establish Task Group on Surface-Materials Interaction............... August 1976
2. Establish preliminary target goals to meet the surface engineering requirements of commercial fusion power................. March 1977
3. Develop detailed surface engineering milestones that complement the Alloy Development Milestones under the Alloy Development and Irradiation Performance Task.................. May 1977
4. Operate surface diagnostics packages on Alcator and ORMAK........... October 1977
5. Begin surface experiments in ISX.................................. December 1977
6. Operate Multiple Beam Radiation Facility (MBRF)..................... September 1979
7. Complete single beam experiments.................................. March 1980
8. Begin surface diagnostics in TFTR................................. October 1981

Summary:

Included in this technical area is work on the plasma interaction with materials. The objectives consist of supporting the alloy development effort as well as support of near term confinement systems. Included are reaction of hydrogen species with surfaces

Title: Special Purpose Materials Development
Contractors: ANL, BNL, LASL, ORNL, PNL

DMFE Program Contact: E. N. C. Dalder

Fiscal Years
Millions

Budget	1976	1976T	1977	1978	1979	1980	1981	1982	FY78-82 Total
Operating	1.17	0.26	0.81	1.0	1.2	1.8	2.3	2.8	9.1
Equipment	0.24	0.02	0.12	0.08	0.1	0.2	0.2	0.3	0.88

Milestones:

1. Evaluate superconducting magnet insulator needs and initiate program......October 1976
2. Evaluate special purpose materials problem areas and develop detailed milestones to meet requirements..................................June 1977

Summary:

This technical area covers all materials requirements other than first wall/structural applications. Included are radiation effects of superconductors, insulators for a variety of applications, moderator and breeding materials, and materials for secondary heat conversion systems.

Title: Damage Analysis and Dosimetry
Contractors: AI, ANL, BNL, HEDL, LASL, ORNL, Universities   DMFE Program Contact: T. C. Reuther

Fiscal Years
Millions

Budget	1976	1976T	1977	1978	1979	1980	1981	1982	FY78-82 Totals
Operating	0.85	0.26	0.61	1.0	2.0	2.2	2.5	2.5	10.2
Equipment	0.18	0.04	0.10	0.03	0.2	0.2	0.3	0.3	1.03

Milestones:

1. Convene DMFE Task Group for Radiation Damage Analysis and Fundamental Studies.................................... September 1976
2. Complete Initial Detailed Program Plan for Damage Analysis... February 1977
3. Complete BCC Charged Particle Intercorrelation Program....... July 1977
4. Characterize d(Be,n) and d(Li,n) in support of Radiation Source Development Program.................................. December 1977
5. Establish intercorrelation among low fluence neutron irradiation test environments for model materials in support of Paths A, B and C of the Alloy Development and Irradiation Performance Task 1980
6. Establish intercorrelation at high damage levels for model materials in a number of irradiation test environments 1983
7. Establish high fluence damage correlation for engineering alloys in fission reactor and d(Li,n) for Path A and Path B 1985

Summary:

The objectives of the Damage Analysis and Dosimetry subprogram are to characterize the irradiation test environment and to establish a basis for predicting materials performance under irradiation in a fusion reactor environment from materials irradiation data obtained in fission reactors, accelerator based neutron test environments (RTNS, INS, d(Li,n), etc.), and charged particle irradiations.

The scope of the Damage Analysis and Dosimetry area includes development and application of the methodology and nuclear data base required for characterization of the neutronic and damage parameters of the reactor and test environments, the development of fundamental radiation damage models, the development of methods to account for interactive phenomena in the evaluation of damage structures, the relationship of structure and damage parameters to property changes, and the application of the above to the prediction of material performance in fusion reactor systems.

Title: Radiation Source Development and Operation
Contractors: ANL, BNL, LASL, LLL, LBL, HEDL, ORNL DMFE Program Contact: M. M. Cohen

Budget	Fiscal Years Millions								
	1976	1976T	1977	1978	1979	1980	1981	1982	FY78-82 Total
Operating Details									
MDF on Multibeam Facility	--	--	--	1.3	0.9	--	--	--	2.2
Multibeam Facility Operation	--	--	--	--	--	0.4	0.4	0.4	1.2
Fission Reactor Operation	--	--	--	0.3	0.6	0.7	0.7	0.7	3.0
D-Be Operation	--	--	--	0.2	0.2	0.2	0.2	0.2	1.0
D-Li Development and Operator Training	--	--	2.35	3.2	2.8	2.4	1.5	1.5	11.4
RTNS Upgrade and Operation	0.50	0.17*	--	0.4	1.8	2.0	2.0	2.0	8.2
INS Upgrade and Operation	0.80	0.18*	--	--	--	--	0.6	2.3	2.9
Miscellaneous	0.53	0.03	0.57	0.1	0.1	0.1	0.1	0.1	0.5
Total Operating	1.83	0.48	2.92	5.4	6.4	5.8	5.5	7.2	30.3
Total Equipment	0.29	0.04	0.30	1.035	1.2	0.7	0.7	0.8	4.43

* Funding and Technical Responsibility Transferred to TPO

Milestones:

1. Decision to develop and build high energy neutron sources with fluxes in the 10^{13}-10^{14}n/cm^2-sec range............................ 1975 Achieved
2. Decision to develop and build a larger volume, high flux (10^{15}n/cm^2-sec) neutron source facility. Select from competing designs.. October 1976
3. Decision to build multibeam test facility incorporating DT-plasma components for surface radiation testing......................... November 1976
4. Operate Rotating Target Neutron Source (RTNS) facility at LLL..... 1978
5. Operate Intense Neutron Source (INS) facility at LASL............ 1981

Summary:

Initial evaluation and development costs to determine suitability of radiation source concepts are included in this area. In cases where a decision is made to construct a facility as a separate line item, the prototype development and construction become the responsibility of the DMFE Technical Projects Office (TPO) after construction authorization. After completion of the facility, its operation becomes the responsibility of DMFE's Development and Technology Program and funds for operation of facilities are included in this data sheet.

Facilities authorized for construction to date include the RTNS at LLL with a projected flux of 2 x 10^{13}n/cm^2-sec and the INS at LASL with a projected flux of 2 x 10^{14}n/cm^2-sec. These facilities will be user oriented and will be utilized for testing and evaluation of the effects of high energy neutrons on reactor structural materials and insulators, as well as for tests to advance the understanding of high energy neutron damage and extrapolation from fission reactor data. Fission reactor radiation facilities and D-Be neutron sources are in existence and funds budgeted reflect operating costs and minor modifications.

Title: d(Li,n) High Energy Neutron Source
Contractor: Unspecified
DMFE Program Contact: K.M. Zwilsky

Fiscal Years
Millions

Budget	1976	1976A	1977	1978	1979	1980	1981	1982	FY78-82 Total
Construction (TEC $70.0M)	--	--	--	8.0	13.0	28.0	17.0	4.0	70.0
Operating	--	--	2.35	3.2	2.8	2.4	1.5	1.5	11.4
Equipment	--	--	0.2	0.4	0.3	0.3	0.1	0.1	1.2

Milestones:

1. Decision to build a large volume, high flux (10^{15} n/cm^2-sec) neutron source facility. Select from competing designs........................ October 1976
2. Begin operation of d(Li,n) neutron source.............................. 1982

Summary:

The d(Li,n)-based neutron source is a high-flux, large-volume, national facility for the development and testing of first-wall, structural materials. This facility has a source strength of 5 x 10^{15} neutrons per second, which yields a volume of 10 cm^3 with a flux of 1 x 10^{15} n/cm^2-sec and a volume of about 600 cm^3 with a flux above 10^{-14}n/cm^2-sec. The high flux is achieved by utilization of the forward-directed neutron emission produced by the impinging of energetic deuterons on a flowing liquid lithium target. This facility will be utilized for the generation of data required for the development and evaluation of new alloys for MFE applications. The high flux will allow for accelerated testing.

Title: Multi-Beam Radiation Facility (MBRF)
Contractor: Unspecified
DMFE Program Contact: K. M. Zwilsky

Fiscal Years
Millions

Budget	1976	1976A	1977	1978	1979	1980	1981	1982	FY78-82 Total
MDF Operating	--	--	--	1.3	0.9	--	--	--	2.2
MDF Equipment	--	--	--	0.5	0.4	--	--	--	0.9
Total MDF				1.8	1.3	--	--	--	3.1
Facility Operation	--	--	--	--	--	0.4	0.4	0.4	1.2

Milestones:

1. Decision to build multibeam test facility incorporating DT-plasma components for surface radiation testing.............................. November 1976
2. Operate facility... October 1979

Summary:

The Multiple Beam Radiation Facility (MBRF) is a National Facility which is intended primarily for surface studies to minimize the introduction of impurities into plasmas. It is designed to expose surfaces to the full range of radiation coming from a burning D-T plasma, including helium ions at 3.5 MeV, helium and hydrogen ions at plasma ion temperatures, electrons and electromagnetic radiation over a range of energies and high energy neutrons from the d(Be,n) reaction. The facility will be utilized for the generation of data required for the development and evaluation of first-wall materials.

Development and Technology Program

Fusion Systems Engineering

Title: Advance Design
Contractors: ANL, HNL, LASL, LLL, PPPL
DMFE Program Contact: J. O. Neff
Group Leaders: W. Stacey (ANL); M. Roberts (HNL);
K. Thomassen (LASL; F. Coensgen (LLL)
E. Frieman (PPPL)

Fiscal Years
Millions

Budget:	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
Operating	4.3	.93	3.4	8.0	9.5	10.5	12.0	16	56.0
Equipment	.03	0	0	0	0	0	0	0	0

Milestones:

1.	Complete preliminary conceptual design of TFTR (PPPL)	June	1974	(achieved)
2.	Complete final conceptual design for TFTR (PPPL)	October	1975	(achieved)
3.	Complete preliminary conceptual design of EPR (ANL, HNL)	June	1976	(achieved)
4.	Initiate conceptual design of PEPR	October	1976	
5.	Identify upgrade design alternatives for PLT, D-III and TFTR	October	1976	
6.	Initiate preliminary conceptual design of FERF	October	1978	
7.	Initiate preliminary conceptual design of Mirror PEPR	October	1979	
8.	Initiate conceptual design for Tokamak EPR	October	1982	
9.	Initiate Mirror Reactor preliminary conceptual (EPR-I) Design	October	1986	

Summary:

Advance Design identifies major fusion facility performance requirements, design goals and alternatives which are needed to achieve commercial fusion power in the late 1990's. Advance Design consists of performing a detailed conceptual design of all identified facility needs as a basis for (1) selecting detailed design alternatives and associated costs and (2) deciding to request authorization to proceed with facility construction and operation. As an example, Advance Design work will include engineering design and costing of the following plant features for the next facility to be constructed in the program.

a) basic design alternatives (e.g., divertor, vs. non-divertor, circular vs. non-circular cross section),
b) basic design characteristics to mitigate plasma physics uncertainties (e.g., alpha-particle heating, fueling problems, impurity control),
c) reactor subsystem design problems (e.g., first wall, shield and blanket, toroidal magnets, energy supply and conversion, reactor maintenance, tritium handling and auxiliary systems).

Title: System Studies
Contractors: ANL, BNL, LLL, LASL, MIT
PPL, Texas, Illinois, Wisconsin, Princeton

DMFE Program Contact: Ron Kostoff

Fiscal Years
Millions

Budget:	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
Operating	2.81	.69	3.5	4.0	4.80	5.55	5.80	6.10	26.25
Equipment	.03	0	0	0	0	0	0	0	0

Milestone:	1. Initiation of systems studies of the following types: . reference designs of fusion power demonstration reactors . reference designs for fusion-fission devices . parametric studies and cost-benefit analyses of fusion power demonstration reactors and fusion-fission devices	July	1975
	2. Initiate assessment of potential of non-electrical fusion applications	October	1976
	3. Completion of reference design and systems studies cited in (1) above	July	1977
	4. Completion of a fusion community-wide technology assessment of alternative fusion reactor concepts and designs	September	1977
	5. Completion of a technical and economic assessment of fusion-fission concepts	September	1977
	6. Periodic reassessment of reactor point designs, parametric analyses, cost-benefit studies and fusion-fission concepts	Continuing	

Summary:

The mission of Systems Studies is to provide the general guidance required for all major aspects of the CTR effort as the program moves toward the goal of commercial fusion power. Four types of studies are involved which identify and assess critical areas of technology and indicate the most favorable paths of fusion power. These are reactor design studies, parametric system analyses, cost-benefit analyses, and new concepts studies.

Title: Blanket and Shield
Contractors: PNL, BNL, LASL, LLL, ORNL, ANL, PPPL   DMFE Program Contact: Bruce Twining

Budget:	Fiscal Years Millions								
	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
Operating	.49	.14	.9	1.8	2.8	4.9	5.0	5.5	20.0
Equipment	.02	.03	.06	.2	.3	.5	.6	.6	2.2

Milestones:	. Nuclear Data		
	- Multigroup cross-section library for MFE use tested & available	June	1976
	- Neutronics data for detailed design of PEPR/ITR is available	January	1980
	- Neutronics data for EPR-I/Demo is complete	September	1985
	. Neutronics Methods Development		
	- Complete update of the Mack Code for use in PEPR/ITR designs	June	1977
	- Complete 2-D S_n code which can handle toroidal problems	September	1977
	- 3-D Monte Carlo Code adapted to toroidal problems and available for general MFE use	September	1979
	. Neutronics Benchmark Calculations & Experiments		
	- Complete initial PEPR/ITR benchmark measurements	June	1979
	- Complete PEPR/ITR engineering mock-up measurements	September	1981
	. Blanket & Shield Engineering Methods Development		
	- Complete technology assessment of current designs	June	1976
	- Identify detailed needs for structural analysis, fabrication techniques & maintenance technology development	September	1977
	- Start preliminary design of Blanket & Shield Test Facility	October	1978
	- Initiate construction of Blanket & Shield Test Facility	October	1980

Milestone:	. Blanket Fabrication & Testing		
	- Start tests on pumping & heat transfer of liquid metals in magnetic fields	October	1977
	- Start hydraulic & heat transfer testing on PEPR/ITR first/wall blanket/shield modules	October	1980
	- Complete feature testing on promising blanket concepts	September	1982
	. Coolant Chemistry & Purification		
	- Start loop tests on impurity monitoring & purification in liquid lithium	October	1979
	- Data sufficient for experimental modules in PEPR/ITR is available	September	1981

Summary:

The mission of Blanket & Shield Engineering is to develop the technology for design, fabrication, and testing of prototype blanket and shield combinations that are candidates for use in experimental and demonstration fusion power reactors. Blanket and Shield Engineering provides for the development of reactor blanket design criteria which balance simultaneous requirements for tritium breeding and removal, heat transfer, structural stability and radiation attentuation as well as structural integrity, reliability, economic viability and minimum activation and afterheat.

Blanket & Shield Engineering is divided into six subprograms. The nuclear data activity assesses MFE data requirements and assures critical data are available in time for facility design. Neutronics methods development provides tools for data processing and nuclear design analysis. The Neutronics Benchmark activity allows for comparison of different calculational methods and the performance of specific integral experiments to verify calculational techniques and final designs. The Blanket & Shield engineering methods development activity provides thermal hydraulic and structural design tools. Thermal and mechanical testing of prototype blanket modules is performed within the blanket fabrication and testing activity. This work could well require a fairly substantial facility investment. Finally, the coolant chemistry and purification activity addresses questions associated with monitoring impurity levels purifying blanket coolants.

Title: Tritium Processing and Control
Contractors: Mound, LLL, LASL, ORNL, ANL

DMFE Program Contact: Bruce Twining

Fiscal Years
Millions

Budget:	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
Operating	.61	.15	1.5	2.3	3.27	3.9	4.95	5.2	19.62
Equipment	.12	.03	.54	.25	.3	.5	.6	.6	2.25

Milestones:		
. Fuel Cycle Reprocessing		
- Initiate design prototype fuel cycle and containment system facility	October	1976
- Initiate tritium operation of fuel cycle and containment system facility	October	1979
- Deliver technology for tritium systems in PEPR	October	1980
. Blanket/Coolant Extraction		
- Initiate design of bench scale lithium loop for tritium extraction tests	January	1976
- Start operation of extraction loop	September	1977
- Initiate design of a prototype extraction loop for the most promising breeding material	July	1979
- Provide technology for EPR tritium extraction systems	September	1984
. Routine/Accident Containment and Cleanup Systems		
- Initiate design of prototype fuel cycle and containment system facility	October	1976
- Begin fabrication of a subsize low permeation heat exchanger	October	1977
- Begin testing of subscale low permeation heat exchanger	January	1979
- Initiate tritium operation of fuel cycle/containment system facility	October	1979
- Deliver technology for tritium systems in PEPR	October	1980

Summary:

The mission of Tritium Processing and Control is as follows: 1) the critical analysis of the projected performance of individual components of tritium handling, subsystems; 2) identification of those alternative components and subsystems which require experimental work, component fabrication, pilot plant demonstration, etc. to provide reliable and safe tritium subsystem performance; and 3) research and development necessary to demonstrate all tritium processing and control subsystems required for each minor fusion facility. Tritium processing and control includes the following major research areas: tritium fuel cycle; blanket tritium extraction systems; tritium isolation in coolant/energy conversion subsystems; and tritium primary and secondary containment/cleanup systems.

Title: **Plasma Systems**
Contractors: **ANL, Illinois, MIT, ORNL, Princeton** DMFE Program Contact: M. R. Murphy

Budget:	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
				Fiscal Years Millions					
Operating	0.33	.08	.70	1.1	1.3	2.0	2.6	3.0	10.0
Equipment	.01	0	0	.1	.1	.1	.2	.2	.7

Milestones:

1. **Initiate analysis of plasma start-up (ANL)**	October	1976
2. **Initiate analysis of fueling/impurity control (ORNL)**	October	1976
3. **Initiate analysis of reactor plasma implications of reverse field concepts (Ill.)**	October	1976
4. **Initiate anslysis of fueling/impurity control (PPPL)**	October	1976
5. **Initiate comparison of r.f. heating schemes**	October	1976
6. **Initiate study of radiation wall loading**	October	1976
7. **Initiate study on reactor relevance of present experiments**	October	1976
8. **Initiate analysis of pellet injection data needs**	October	1976

Title: Plant Systems
Contractors: Charles Stark Draper Laboratories

DMFE Program Contact: B. G. Twining

Fiscal Years
Millions

Budget:	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
Operating	.13	.02	.3	.8	1.33	3.15	4.05	4.1	13.43
Equipment	0.01	0	0	.09	.1	.3	.3	.3	1.09

Milestones:

Milestone	Month	Year
. Initiate Study on Tokamak Maintenance Options	October	1976
. Complete Initial Studies on Computer Instrumentation and Control Systems	October	1977
. Complete Initial Study of Tokamak Maintenance	September	1977
. Initiate Study of reliability requirements for fusion reactors	October	1977
. Complete Detailed Assessment of Fusion Reactor BOP Development Needs	July	1978
. Initiate development on fusion power plant systems, eg., steam generators, valves, control equipment	October	1978
. Complete tests of PEPR reactor and plant control scenarios on existing fusion experiments and/or control simulators	September	1983

Summary:

Plant Systems is an activity which addresses problems of a general systems nature which would not fall within the other five categories of Fusion Systems engineering. Two presently identified areas are reactor system instrumentation and control and reactor system and balance of plant radiation engineering. Other potential areas of study include balance of plant systems requirements (energy conversion, seismic design requirements, identification of large component development needs, etc.) and systems and component reliability. Additional subjects may be added as important systems problems are identified.

Development and Technology Program

Environment and Safety

Title: Environmental Assessment
Contractors: PNL, Other ERDA Laboratories and Contractors DMFE Program Contact: J. E. Baublitz

Fiscal Years
Millions

Budget:	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
Operating	.45	.11	0.25	0.3	.7	1.0	0.6	0.6	3.2
Equipment	0	0	0	0	0	.05	.05	.06	.16

Milestone:

1.	Approve Environmental Statement for TFTR:	June	1975
2.	Review Environmental Analysis of Fusion R&D Program	October	1976
3.	Approve Environmental Statement for LASL INS	July	1976
4.	Approve Environmental Statement for PEPR		1979
5.	Approve fusion power R&D program Environmental Statement		1980

Summary:

The purpose of this program is to assure that environmental considerations are factored into decisions to construct and operate major fusion facilities which could have significant environmental impacts. The intent is 1) to publish an Environmental Statement (ES) for each major facility, and 2) to prepare an ES for the overall fusion power R&D program (at such time as adequate information is available to meaningfully examine the environmental implications of a national fusion power program). In anticipation of the program ES need, DMFE began funding a comprehensive environmental analysis effort at PNL in FY 1976, and it is planned for completion in FY 1976A.

Title: Facility Safety Analysis
Contractors: To be determined

DMFE Program Contact: J. E. Baublitz

Budget:

	Fiscal Years Millions								
	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
Operating	0	0	0.1	0.1	0.3	0.5	0.6	0.9	2.4
Equipment	0	0	0	0	0	0	0	0	0

Milestones:

1.	Approve PSAR for TFTR	July 1977
2.	Approve PSAR for INS	1978
3.	Approve FSAR for INS	1980
4.	Approve PSAR for PEPR	1981
5.	Approve FSAR for TFTR	1981
6.	Approve FSAR for PEPR	1985

Summary:

The objective of Preliminary Safety Analysis Reports (PSAR's) is to assess the safety of a plant in the early design stages to assure adequate incorporation of plant safety features into facility design and construction and to assure that, prior to facility operation, all such plant safety features are operational and adequate to protect plant personnel and the public. These safety analyses will draw upon background material and analytical tools (e.g., failure rate data files, previous accidents and safety studies, and safety analysis formalisms and computer simulation programs) developed from the Reactor Safety Research Program. A Final Safety Analysis Report (FSAR) is issued when the facility construction is complete.

Title: Fusion Reactor Safety Research
Contractors: To be determined
Group Leaders: To be determined

DMFE Program Contact: J. E. Baublitz

Fiscal Years
Millions

Budget:	1976	1976A	1977	1978	1979	1980	1981	1982	FY 78-82 Total
Operating	0	0	0.6	0.6	1.0	1.5	2.2	2.4	7.7
Equipment	0	0	0	.12	0.2	.25	.25	.34	1.16

Milestones:		
1.	Development of a safety research program plan	1978
2.	Development and maintenance of component and system failure rate data files	Continuing
3.	Safety research to define fusion reactor potential risks (e.g., loss of coolant accidents, fires, electrical failures) and development of engineered safeguards against such risks.	Continuing
4.	Proof-testing of integrated safety systems (e.g., containment/ cleanup systems)	

Summary:

The objectives of this program are to identify and characterize the accident risks of fusion power reactors and develop the methodology and engineered safeguards necessary to provide for safe construction and operation of fusion power reactors. Examples of topics to be covered include: loss of coolant accidents; tritium release accidents; natural phenomena such as earthquakes, tornado and floods; magnet safety; turbine run away; remote maintenance and handling; and waste disposal.

Applied Plasma Physics

Theory

Plasma Properties - Theory

	Projected Budget $K							
Research Activity	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
Tokamak	$ 3,000	$ 800	$ 3,000	$ 3,100	$ 3,500	$ 3,800	$ 3,900	$ 3,600
Advanced Concepts...	2,000	640	2,310	2,400	2,800	3,800	3,900	3,600
Supporting Physics..	0	0	0	130	700	600	500	1,200
Total Operating	$ 5,000	$ 1,440	$ 5,310	$ 5,630	$ 7,000	$ 8,200	$ 8,300	$ 8,400

Milestones

1.	Quasilinear model of turbulent confinement in mirrors (LLL).	Achieved
2.	Determine transport and scaling arising from trapped particle instabilities (Various sites).	Early 1976
3.	Determine the detailed dependence of low frequency drift dissipative and trapped particle instabilities on system parameters and apply the results to fusion devices (PPPL, ORNL, Texas, NRL).	Mid 1976
4.	Determine the effect of impurities on plasma particle and heat transport, energy balance, and stability and apply the results to future fusion devices (various sites).	Late 1976
5.	Alfven Ion Cyclotron Mode Stability boundaries (LLL).	Late 1976
6.	Quasilinear model of turbulent confinement in mirrors extended to model MX (larger radii) (LLL).	Late 1976
7.	Develop a theory of Guiding Center Stability for high beta 3-D minimum B mirror configurations (LLL).	Early 1977
8.	Q-enhancement to include but not exclusive; survey with bounced-averaged F.P., r.f. stoppering, high beta and reversed field configurations, time dependent mirror cycling (LLL).	Mid 1977
9.	Construction of a code to model neutral beam deposition into mirrors (LLL).	Mid 1977
10.	Theoretic models of negative ion formation implemented into computer codes (LLL).	Late 1977

11. Quasilinear model of turbulent confinement in mirrors extended to model MX and incorporates radial transport due to turbulence (LLL). 1978
12. Develop nonlinear models to describe magnetic surface breakup and plasma transport associated with the disruptive instability, and other gross instabilities (site undetermined). 1979
13. Develop and apply new techniques for non-linear equations of plasma physics in complex realistic magnetic field configurations (various sites). 1977-1982

Plasma Production and Heating - Theory

Research Activity	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
	Projected Budget $K							
Tokamak	$ 500	$ 140	$ 520	$ 700	$ 830	$ 1,000	$ 1,000	$ 900
Advanced Concepts ...	0	0	0	300	390	480	500	600
Supporting Physics...	0	0	0	0	0	0	0	0
Total Operating	$ 500	$ 140	$ 520	$ 1,000	$ 1,220	$ 1,480	$ 1,500	$ 1,500

Milestones

1.	Derive a generalized formulation of ponderomotive effects for nonlinear interactions in a magneto plasma (LBL).	Jan. 1976 (Achieved)
2.	Determine the nonlinear processes involved in lower hybrid plasma heating (Stevens).	Jan. 1976 (Achieved)
3.	Extend the development of two-dimensional time-dependent transport codes and apply to auxiliary heating for current profile control (GA).	Feb. 1976 (Achieved)
4.	Investigate diffusion and heating of particles by a single oblique wave in a magneto plasma as a heating method (LBL).	June 1976 (Achieved)
5.	Determine the characteristics of waves in periodically varying magnetic fields (SAI).	June 1976 (Achieved)
6.	Examine the growth rate of instabilities produced by lower hybrid pump waves to study plasma heating by the lower hybrid pump (Iowa).	June 1976 (Achieved)
7.	Extend present initial dynamics codes for screw pinches and belt pinches to high beta tokamaks and helical systems. They will also be extended to longer running times so as to obtain the approach to equilibrium (Columbia).	Aug. 1976
8.	A complete initial study of nonlinear concepts of velocity space in stabilities associated with intense parallel or perpendicular heating injections (PPPL).	Dec. 1976

9.	Assess the theoretical expectations for all heating in large tokamaks, considering nonlinear limits on lower hybrid heating, and for Fokker-Planck simulations of ion-cyclotron heating (PPPL).	Dec. 1976
10.	Develop a theoretical description of RF heating, including lower hybrid, ICRH, and Alfven and apply the results to confinement devices (PPPL), (ORNL).	Feb. 1977
11.	Study the dynamics of L-H heating for tokamak applications (MIT).	Oct. 1977
12.	Develop nonlinear theories to determine saturation levels and anomalous transport coefficients in high beta confinement systems (Maryland).	Oct. 1977
13.	Complete application of hybrid kinetic model to determine influence of finite electron pressure and electron kinetic effects on theta pinch stability behavior (Maryland).	Oct. 1977
14.	Complete investigation of classical neutral beam energy deposition in a tokamak (ORNL), (PPPL).	Nov. 1977

Computer Applications - Theory

Research Activity	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
	Projected Budget $K							
Tokamak.............	$ 3,600	$ 1,000	$ 4,000	$ 5,000	$ 5,700	$ 7,000	$ 7,100	$ 7,100
Advanced Concepts ...	2,590	800	3,000	3,600	4,400	5,300	5,400	5,400
Supporting Physics...	280	120	300	400	400	500	350	500
Total Operating	$ 6,470	$ 1,920	$ 7,300	$ 9,000	$10,500	$12,800	$12,850	$13,000

Milestones

1. Develop a numerical technique which will evolve into a production code for solving 2D initial value problems for ideal MHD and realistic equilibria (various sites). July 1975 (Achieved)
2. Complete preliminary calculations of the mode structure of lower hybrid heating for application to ATC (PPPL). July 1975 (Achieved)
3. Complete initial phase of calculations of equilibrium and stability of PDX using codes developed in FY 1973/74 (PPPL). July 1975 (Achieved)
4. Complete preliminary calculation of the opacity to cyclotron (synchrotron) radiation of an equilibrium plasma as a function of frequency, direction, and polarization (SAI). Fall 1975 (Achieved)
5. Develop and apply 1-D hybrid code to tokamak geometry for the study of skin phase of discharge (SAI, PPPL,ORNL) Fall 1975 (Achieved)
6. Complete preliminary calculations for mirror systems using Fokker-Planck codes with neutral beam injection, charge exchange, and ionization effects included (LLL). Fall 1975 (Achieved)
7. Computer simulation of high β mirrors and field-reversed configurations (LLL). Late 1975 (Achieved)
8. Develop a 2-D transport code for non-circular cross sections that will be applied to the Doublet machines prior to the formation of magnetic x-points (SAI). July 197 (Achieved)

9.	Modify bounce averaged Fokker-Planck code to include:	
	(a) coupling to quasilinear turbulence model (LLL)	Mid 1976
	(b) general field shapes (LLL)	Late 1976
	(c) include effects of magnetic moment invariant breakdown (LLL)	Late 1976
	(d) development of multispecies version (LLL)	Mid 1977
	(e) coupling to enhanced scattering due to convective loss modes (LLL)	Mid 1977
10.	Complete investigation of classical neutral beam energy deposition in a tokamak (PPPL, ORNL, GA, MIT).	Early 1977
11.	Develop a theoretical description of RF heating, including lower hybrid, ICRH, and Alfven and apply the results to confinement devices (PPPL).	Mid 1977
12.	Develop a hybrid code to describe implosion heating and profile evaluation in THOR-toroidal theta pinch (Maryland).	June 1977
13.	Couple 3-D high β equilibrium code to F.P. and radial buildup codes (LLL).	Mid 1977
14.	Conduct MHD stability studies for geometry and parameters appropriate to TERP-high beta tokamak (Maryland).	Oct. 1977
15.	Develop realistic time-dependent macroscopic fluid models to describe plasmas on the fast Alfven time scale and on the slower magneto-acoustic time scale (site undetermined).	Late 1977
16.	Update the physics of high beta mirror and field-reversal codes to include electron dynamics and effects of electromagnetic instabilities (LLL).	Late 1977
17.	Develop code to model gas feed experiments in mirrors (LLL).	1978
18.	Develop and apply realistic particle simulation codes (site undetermined).	1978
19.	Complete analysis of the production and effects of electron runaways (ORNL, MIT, NRL).	1978
20.	Develop and apply realistic 3-D codes to describe MHD equilibrium and evaluate stability criteria (LASL, NYU, ORNL, PPPL).	1978
21.	Describe the equilibrium, stability, and transport of a two-component reactor in tokamak geometries (PPPL).	1978
22.	Model the plasma physics in the vicinity of the scrape off region of a divertor (PPPL).	1978
23.	Develop realistic distribution function codes (ORNL).	1979
24.	Develop codes to model burning plasma systems, including reactors and apply these to reactor designs (site undetermined).	1979

Atomic, Molecular and Nuclear Physics - Theory

Research Activity	Projected Budget $K							
	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
Tokamak	$ 330	$ 100	$ 470	$ 820	$ 990	$ 1,100	$ 1,000	$ 850
Advanced Concepts....	0	0	0	0	0	0	0	0
Supporting Physics...	0	0	0	0	0	0	0	0
Total Operating	$ 300	$ 100	$ 270	$ 820	$ 990	$ 1,100	$ 1,000	$ 850

Milestones

1. Complete examination of bremsstrahlung, ionization and radiative excitation processes which occur between an electron and a partially stripped ion and apply the results to operating confinement systems (Sandia).	Mid 1976
2. Calculate synchrotron radiation from tokamak plasmas (SAI).	Mid 1977
3. Calculate nuclear cross sections in close support of experimental effort (site undetermined).	Mid 1977
4. Complete study of recombination processes under same conditions as above (LASL, NBS, Universities).	Early 1978
5. Perform theoretical calculations of surface physics and apply these to existing and future confinement devices (site undetermined).	Early 1979

Exploratory Concepts - Theory

Research Activity	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
	Projected Budget $K							
Tokamak	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
Advanced Concepts.....	0	0	0	1,250	1,290	1,420	1,350	1,250
Supporting Physics...	0	0	0	0	0	0	0	0
Total Operating	$ 0	$ 0	$ 0	$ 1,250	$ 1,290	$ 1,420	$ 1,350	$ 1,250

Milestones

1.	Develop a numerical code to solve 3-D equilibrium for EBT (high-beta, anisotrophy realistic radial profiles (ORNL).	Jan. 1976 (Achieved)
2.	Provide a theoretical capability in support of TORMAC at LBL (DMFE)	Oct. 1976
3.	Develop a hybrid code for study of low frequency modes in ion rings (Cornell).	Dec. 1976
4.	Apply the new description of plasmas developed at Boston College to TORMAC (PPPL).	June 1977

Applied Plasma Physics

Experimental Plasma Research

Plasma Properties - Experimental

	Projected Budget $K							
Research Activity	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
Transport and Scaling Laws...............	$ 830	$ 405	$ 1,345	$ 1,300	$ 1,570	$ 1,630	$ 1,535	$ 1,450
	(340)	(300)	$ 150)	(180)	(200)	(230)	(150)	(200)
Divertor Simulation...	140	115	225	185	230	260	200	155
	(20)	(20)	(10)	( )	(100)	(50)	(50)	(50)
High Beta Toroidal ...	320	150	330	520	625	610	525	465
	(205)	( )	(250)	(220)	(150)	(100)	(100)	(50)
End Loss	300	55	225	295	275	300	240	230
	(60)	(5)	(15)	( )	(50)	(70)	(50)	(50)
Total Operating	$ 1,590	$ 725	$ 2,125	$ 2,300	$ 2,700	$ 2,800	$ 2,500	$ 2,300
Equipment	(625)	(325)	(425)	(400)	(500)	(450)	(350)	(350)

Milestones (Transport and Scaling Laws)

1. Move levitated octupole from the remote site to the campus (U. of Wisc.) November 1974 (Achieved)
2. Complete experimental investigations of the effects of intense EM heating fields on collision rates (LASL). July 1975 (Achieved)
3. Complete fabrication and begin operation of Microtor, a small tokamak device for energy and particle transport studies (UCLA). November 1975 (Achieved)
4. Complete measurements and identification of lower hybrid resonance effects in a linear device (UCLA). Dec. 1975 (Achieved)
5. Complete measurements and analysis to determine the mechanisms which generate runaway electrons in a typical Ormak discharge (ORNL). June 1976 (Achieved)
6. Complete the study of ion-cyclotron instabilities driven by ion beam injection (PPPL). June 1976 (Achieved)
7. Complete Major Device Fabrication Review (MDFR) for the Microtor/Macrotor project. Project approved for fabrication, operation and experimental investigation with Macrotor B_T up to 10 kG (UCLA). June 1976 (Achieved)
8. Complete preliminary impurity control investigations as to their effects on tokamak scaling laws (UCLA). Jan. 1977
9. Complete fabrication and begin operation of Versator II (MIT). Jan. 1977

10. Achieve an understanding of studies of B independent of 1/n diffusion (U. of Wisc.).	May 1977
11. Achieve an understanding of diffusion scaling for the trapped ion regime (U. of Wisc.).	May 1977
12. Complete the assessment of the role of runaway electrons on plasma stability, equilibrium and impurity evolution (ORNL).	June 1977
13. Obtain preliminary results of the transport effects due to trapped ion instabilities in a levitated octupole (U. of Wisc.)	June 1977
14. Major Device Fabrication Review (MDFR) to upgrade Macrotor to B_T of 30 kG (UCLA).	Jan. 1978
15. Complete the study of skin effect and channel formation in the limits of strong and weak ohmic heating (UCLA).	

Milestones (Divertor Simulation)

1. Complete assembly of the QED-1 device for divertor simulation studies (PPPL).	June 1976 (Achieved)
2. Complete detailed measurements of scrape-off zone plasma with existing source using the single ring DC Machine (Wisconsin).	Dec. 1976
3. Extend the electrostatic divertor geometry and plasma parameters in the octupole (Wisconsin).	Dec. 1976
4. Complete preliminary experimental test of Tenney gaseous collector model for a divertor (PPPL).	June 1977
5. Complete preliminary electrostatic divertor action studies caused by E x B drifts in the levitated octupole (U. of Wisconsin).	Aug. 1977
6. Complete measurements and analysis of scrape-off zone plasma with higher density source using the single ring DC machine (Wisconsin).	Sept. 1977
7. Complete evaluation of shock formation at the plasma-gas interface of Tenney gaseous collector (PPPL).	Jan. 1978
8. Complete the evaluation of emission of impurities by the divertor into the main plasma (PPPL).	June 1978

Milestones (High Beta Toroidal)

1. Begin operating Torus I in belt pinch mode (Columbia).	Nov. 1975 (Achieved)
2. Begin operating Torus I in high beta tokamak mode (Columbia).	Jan. 1976 (Achieved)
3. Complete Major Device Fabrication Review (MDFR) for Torus II. Torus II approved for fabrication, operation and high beta experimental investigations (Columbia).	April 1976 (Achieved)
4. Complete preliminary survey of Torus I operation as a belt pinch (Columbia).	June 1976 (Achieved)
5. Complete preliminary survey of Torus I operation in a high beta tokamak mode (Columbia).	Sept. 1976

6. Complete B, n, T and v measurements for the study of equilibrium, transport and stability in the collisional (P-S) non-circular high beta tokamak regime (Maryland). Dec. 1976
7. Major Device Fabrication Review (MDFR) to evaluate upgrading TERP to investigate high beta equilibrium, transport and stability in the neoclassical regime (Maryland) Jan. 1977
8. Complete compression, ohmic heating, equilibrium and stability studies in Torus I (Columbia). Oct. 1977
9. Complete assembly and begin operation of Torus II (Columbia). Jan. 1978
10. Complete preliminary survey of Torus II operation (Columbia). Summer 1978

Milestones (End Loss)

1. Complete the measurements and analysis of transient flow from a 25 cm linear theta pinch (Penn State) March 1977
2. Complete assembly and preliminary testing of a 50 cm linear theta pinch with crowbar and mirror circuitry (Penn State) March 1977
3. Complete the investigations of the effects of electrostatic trapping potentials on heat flow in a linear magnetically confined plasma (LASL). June 1977
4. Complete preliminary measurements of end loss processes with mirrors in a linear theta pinch (Penn State). Oct. 1977
5. Complete measurements of end loss processes with mirrors in a linear theta pinch (Penn State). Oct. 1978

Plasma Production and Heating - Experimental

	Projected Budget $K							
Research Activity	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
RF Heating	$ 690	$ 300	$ 1,605	$ 1,890	$ 2,010	$ 2,200	$ 2,025	$ 1,980
	(70)	(30)	(100)	(100)	(200)	(200)	(100)	(150)
Ion and Plasma Sources.	305	70	325	510	590	600	575	520
	(70)	(20)	(20)	(100)	(200)	(100)	(100)	(50)
Implosion Heating......	815	165	450	0	0	0	0	0
	(220)	(75)	(30)					
Turbulent Heating	850	200	0	0	0	0	0	0
	(115)							
Total Operating	$ 2,660	$ 735	$ 2,380	$ 2,400	$ 2,600	$ 2,800	$ 2,600	$ 2,500
Equipment.........	(475)	(125)	(150)	(200)	(400)	(300)	(200)	(200)

Milestones (RF Heating)

1. Complete quantitative measurements of OH, ICRH and ECRH on the supported octupole for q values near the tokamak regime (Wisconsin).	June 1975 (Achieved)
2. Complete assembly and begin initial operation of a research tokamak for plasma heating studies (Cal. Tech.).	Feb. 1976 (Achieved)
3. Complete the efficiency and spatial localization investigations of LHRH in a linear device and initiate ICRH studies (PPPL).	June 1976 (Achieved)
4. Complete the study of ICRH wave penetration and absorption as a function of toroidal field strength and plasma density in a supported octupole at a power level of 1 MW (Wisconsin).	June 1976 (Achieved)
5. Modify ICRH system to raise T_i to 800 eV. Present system - T_i increases from 1 eV to 350 eV with 1 MW (Wisconsin).	Nov. 1976
6. Determine the feasibility of ECR breakdown in a simulated tokamak plasma and the effectiveness of ECRH for discharge cleaning (Wisconsin).	Nov. 1976
7. Test penetration of LH waves in octupole plasmas at 1 kW level. If successful extend to 10 kW level (Wisconsin).	Nov. 1976
8. Complete preliminary measurements and analysis of ICR wave mode structure, propagation characteristics and energy deposition mechanisms (Cal. Tech.)	May 1977

9. Complete preliminary survey of spontaneous radiation in the microwave range to determine whether significant radiation near the ion plasma frequency is present, as observed in Alcator (Cal. Tech.) — May 1977
10. Complete the efficiency, wave absorption and spatial localization investigations of ICRH in a linear device (PPPL). — June 1977
11. Complete coupler design, wave absorption and efficiency studies for ICRH in a research tokamak (Cal. Tech.) — Jan. 1978
12. Complete preliminary coupler design, wave absorption and efficiency studies for LH heating in a research tokamak (Cal. Tech.). — June 1978

Milestones (Ion and Plasma Sources)

1. Complete the production of a beam of negative (H^-) ions using a NaH target irradiated with a CO_2 laser beam (UCLA). — Oct. 1974 (Achieved)
2. Initial test results for a plasma accelerator (deflagration plasma gun) designed for a pulse duration of 50 to 100 μsec (Santa Clara). — May 1976 (Achieved)
3. Complete the evaluation of the best cathode configuration for a neutral beam source (MIT). — June 1976 (Achieved)
4. Complete measurements and evaluation of the electrical and gas flow efficiency, beam divergence and ionic composition of a typical LBL neutral beam source (LBL). — Sept. 1976
5. Complete the design of an improved positive ion source (LBL, MIT). — Jan. 1977
6. Complete testing and analysis of three plasma guns (6, 12 and 50 kJ) to determine the required scaling laws (Santa Clara). — Jan. 1977
7. Complete experimental investigations necessary to verify that a 1 to 5 amps negative ion source can be developed using production at a solid surface (LBL). — June 1978

Milestones (Implosion Heating)

1. Complete assembly and begin operation of the linear Implosion Heating Experiment - IHX (LASL). — Feb. 1975 (Achieved)
2. Complete the evaluation of neutral background effects on magnetic piston and current sheath development in a linear theta pinch (Texas). — Feb. 1976 (Achieved)
3. Complete assembly and begin operation of a toroidal shock heated theta pinch - THOR (Maryland). — Aug. 1976
4. Complete measurements and analysis of the ion heating dependence on plasma density and piston amplitude in a linear theta pinch - IHX (LASL). — Sept. 1976

5. Preliminary plasma parameter measurements for implosion heating in a toroidal configuration (Maryland). Dec. 1976
6. Complete implosion heating investigations and analysis for the toroidal configuration - THOR (Maryland). Oct. 1977

Milestones (Turbulent Heating)

1. Complete ion-acoustic turbulence studies (Maryland). Dec. 1975 (Achieved)
2. Transfer TTT experiment from Confinement Systems to Applied Plasma Physics (Texas). Dec. 1975 (Achieved)
3. Complete turbulence/REB heating studies in a mirror geometry (Cornell) Jan. 1976 (Achieved)
4. Complete the evaluation of the experimental results as compared to the theoretical predictions for turbulent heating in TTT (Texas). Oct. 1976

Measurements and Instrumentation - Experimental

Research Activity	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
	Projected Budget $K							
New Diagnostic Techniques	$ 820	$ 310	$ 1,740	$ 2,385	$ 2,470	$ 2,570	$ 2,300	$ 2,100
	(305)	(140)	(305)	(300)	(400)	(300)	(200)	(200)
Advanced Data Acquisition	90	30	200	300	320	345	400	400
	(70)	(10)	(45)	(50)	(50)	(75)	(100)	(100)
Measurement Standards.	150	40	160	150	160	185	200	200
				(50)	(50)	(75)	(50)	(50)
Total Operating	$ 1,060	$ 340	$ 2,100	$ 2,735	$ 2,950	$ 3,100	$ 2,900	$ 2,700
Equipment.......	(375)	(150)	(350)	(400)	(500)	(450)	(350)	(350)

Milestones (New Diagnostic Techniques)

1. Complete preliminary testing of a CH_3F laser providing over 200 kW of 0.496 micron radiation (MIT). March 1976 (Achieved)
2. Complete the assembly of an electrostatic multichannel neutral atom spectrometer for Alcator (MIT). April 1976 (Achieved)
3. Complete preliminary testing of a CO_2 forward scattering and an optical homodyone detection system to measure low frequency drift-type oscillations in plasma (UCSD). May 1976 (Achieved)
4. Operate 1 MV CH_3F laser pumped by 150 J CO_2 laser (ORNL) Jan. 1977
5. Operate CH_3F laser interferometer on ORMAK (ORNL). Jan. 1977
6. Measure synchrotron emission on PLT (Maryland). April 1977
7. Develop 200 kW far IR CH_3F laser system with 10^{-18} watts/Hz Schottky detectors (MIT).
8. Compare ion beam temperature measurements with Thomson scattering measurements on a Versator type of Tokamak (RPI). July 1977
9. Develop small extreme UV and soft x-ray spectrographic equipment and measure impurity concentrations on Tokamaks (Johns Hopkins, NRL). Aug. 1977

10. Develop and test CO_2 forward scattering techniques for density fluctuation measurements (UCSD, MIT). Oct. 1977
11. Develop high resolution x-ray spectrometer for Ti measurement by Doppler broadening (Harvard). Dec. 1977
12. Install CH_3F laser system on plasma device (MIT, ORNL). Jan. 1978
13. Develop B-field measurement techniques from optical emissions from probe beams (MIT, undesignated). April 1978
14. Develop current density measurement techniques (RPI, Others). June 1978

Milestones (Advanced Data Acquisition)

1. Develop space-resolved Thomson scattering instrumentation for theta pinch plasmas (LASL). Oct. 1977
2. Develop instrumentation for storage retrieval, processing and display of signals in flexible formats including two dimensional displays of signals (LASL). Oct. 1978

Milestones (Measurement Standards)

1. Complete the UV radiometric standards facility (SURF-II) and begin calibrating spectrometer equipment (NBS). Jan. 1976 (Achieved)
2. Complete neutron standards measurements for CTR using ^{235}U, ^{237}Np and ^{6}Li (NBS). June 1976 (Achieved)
3. Develop monoenergetic K x-ray beams at less than 1.5 keV beam energy and at higher intensities than currently available sources (NBS). Jan. 1977
4. Develop simple low cost UV calibration sources (undesignated). Jan. 1978
5. Provide standard sources and calibration facilities for CTR spectroscopy (NBS). Jan. 1979

Atomic, Molecular and Nuclear Physics - Experimental

Research Activity	Projected Budget $K FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
Impurity Data	$ 1,015	$ 360	$ 1,540	$ 1,880	$ 1,950	$ 1,900	$ 1,800	$ 1,700
	(125)	(20)	(50)	(100)	(200)	(100)	(50)	(25)
Surface Effects	75	10	170	370	600	825	900	900
					(150)	(100)	(25)	(25)
Data Centers	150	60	210	220	260	275	300	250
					(50)	(50)	(25)	(25)
Nuclear Data	50	15	80	230	290	500	600	650
					(100)	(100)	(150)	(175)
Total Operating	$ 1,290	$ 445	$ 2,000	$ 2,700	$ 3,100	$ 3,500	$ 3,600	$ 3,500
Equipment	(125)	(20)	(50)	(100)	(500)	(350)	(250)	(250)

Milestones (Impurity Data)

1. Complete absolute cross section measurements for thalium by electron impact ionization for electron energies up to 2 keV (Ga. Tech.).	Jan. 1975 (Achieved)
2. Complete absolute electron impact ionization cross section measurements for Cs^+ and Rb^+.	Aug. 1975 (Achieved)
3. Complete assembly and initial tests of a theta pinch facility (NBS).	Jan. 1976 (Achieved)
4. Complete electron capture cross sections for C^{n+}, N^{n+} and O^{n+} in H_2 for n = 3, 4 and 5 (ORNL).	June 1976 (Achieved)
5. Initiate rate coefficient measurements in theta pinch facility (NBS).	June 1976 (Achieved)
6. Complete electron-impact excitation and ionization cross section measurements for Li-like ions (Be II, C IV, O VI). (JILA).	Dec. 1976
7. Complete charge exchange cross section measurements of C^{n+}, O^{n+} and Fe^{n+} with H^o energy range 20-150 keV (ORNL).	Dec. 1976
8. Measure and interpret Mo and Au x-ray wavelengths in laser and spark plasmas (NRL).	April 1977

9.	Complete ionization cross section measurements for H^{o} on C^{n+}, O^{n+}, N^{n+} and Fe^{n+} (ORNL).	Jan. 1978
10.	Determine primary processes and reaction rates for formation of negative deuterium ion in gases and at surfaces (LBL, SRI).	Jan. 1978
11.	Extend electron cross section measurements to heavy impurities (JILA, ORNL, NBS).	June 1978
12.	Identify resonance lines for one-electron and rare-gas-like ions of heavy elements through Au XI and Au XII (NBS).	Sept. 1978
13.	Complete development of negative ion source theoretical model (LBL).	Jan. 1979
14.	Obtain stripping data for deuterium beams in relevant target gases (LBL)	March 1979
15.	Extend charge exchange measurements to heavy elements (ORNL, LBL, NRL).	Jan. 1980
16.	Provide tables of x-ray and UV lines of CTR interest to between 0.01 and 0.1 Å accuracy (NBS, NRL, Others).	March 1980
17.	Provide data for EPR neutral beam development (LBL, SRI, Others)	March 1980

Milestones (Surface Effects)

1.	Complete H^{o} reflection measurements of energy and angular distributions (ORNL).	Oct. 1976
2.	Measure charge state distribution and excited state percentages of backscattered H atoms when 5-30 keV H^+, H^{o} and H_2^+ are incident on C, Au, Nb, Ta and W targets (Ga. Tech.).	Feb. 1977
3.	Obtain reflected neutral particle data as a function of energy (ORNL, Ga. Tech.).	Jan. 1979
4.	Determine charged particle emission from surfaces by scattering of incident particles (Ga. Tech., ORNL).	June 1979
5.	Complete measurements of D^{o} desorption by photons, electrons and deuterium (ORNL, U. Va.).	Jan. 1980
6.	Provide surface data for EPR design.	March 1980
7.	Characterize plasma impurity contamination by deuterium and neutron sputtering (undesignated).	June 1980

Milestones (Atomic Data Center)

1.	Compile, evaluate and distribute atomic data.	Continuing
2.	Initiate critical evaluation of atomic data.	Oct. 1977
3.	Provide computer access to data by terminals.	June 1979

Milestones (Nuclear Data)

1.	Complete D-T cross section measurement (NBS).	Oct. 1976
2.	Initiate expanded program in nuclear dosimetry and breeding data (NBS, LASL).	March 1977
3.	Initiate program on neutron detection for Ti diagnostics (undesignated).	Oct. 1979
4.	Provide breeding, dosimetry and diagnostics data for EPR design.	March 1980

Fusion Plasma Research Facility - FPRF

	Projected Budget $K							
Research Activity	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
FPRF Operating	$ 0	$ 0	$ 3,000	$ 3,000	$ 2,500	$ 2,600	$ 2,700	$ 2,800
Equipment			(1,000)	(1,000)	(600)	(650)	(700)	(500)

Milestones

1.	Report of the Ad Hoc Committee on Fusion Plasma Research Facilities completed, ERDA-106.	1975 (Achieved)
2.	Major Device Fabrication Review (MDFR) for a proposed FPRF - tokamak type (Texas).	Aug. 1976
3.	Complete final conceptual designs (Texas).	Feb. 1977
4.	Complete assembly and test of first homopolar generator (Texas).	Feb. 1978
5.	Complete tokamak facility assembly and test (Texas).	Feb. 1979

Exploratory Concepts - Experimental

Research Activity	Projected Budget $K FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
Toroidal Systems	$ 150	$ 60	$ 400	$ 1,100	$ 1,050	$ 1,600	$ 1,000	$ 1,100
			(50)	(500)	(500)	(500)	(300)	(600)
Linear Systems	1,630	600	1,695	700	700	650	700	600
	(665)	(80)	(100)	(100)	(200)	(400)	(500)	(200)
Field Reversal	275	25	850	965	1,000	1,200	2,600	3,100
	(35)		(75)	(100)	(700)	(200)	(950)	(1,400)
Liner Flux Compression.	100	115	1,250	1,300	1,400	1,400	1,400	1,400
			(200)	(100)	(500)	(700)	(400)	(650)
Non-Magnetic Confinement	45	55		200	300	350	0	0
				(100)	(100)		0	0
Total Operating	$ 2,200	$ 855	$ 4,195	$ 4,265	$ 4,450	$ 5,200	$ 5,700	$ 6,200
Equipment	(700)	(80)	(425)	(900)	(2,000)	(1,800)	(2,150)	(2,850)

Milestones

1. Preliminary experimental results on plasma heating with a rotating relativistic E-beam (UC/Irvine). June 1976 (Achieved)
2. Produce plasma confinement in enlarged electro-static well (Illinois). June 1976 (Achieved)
3. Begin investigation of stabilization of presently known instabilities in E-layers in as Astron type facility (Cornell). Aug. 1976
4. Experimental determination of plasma heating rates using weak shock heating in Tormac (Shaker) experiment (LBL). Aug. 1976
5. Initiate staged heating experiment in CO_2 laser heated solenoid (MSNW, Washington). Aug. 1976

6.	Production of high aspect ratio CO_2 laser-heated, dense, magnetized plasma (MSNW).	Dec. 1976
7.	Begin operation of improved multiple mirror confinement experiment (UC/Berkeley).	Dec. 1976
8.	Determine Tormac sheath structure (LBL).	Dec. 1976
9.	Begin start-up and refueling experiments in Tormac program (LBL).	March 1977
10.	Begin captive liner flux compression experiments (NRL).	March 1977
11.	Evaluate plasma formation experiments for liner compression experiments (NRL).	July 1977
12.	Preliminary results for proof-of-concept for CO2 laser heated solenoid (MSNW).	July 1977
13.	Initiate studies of plasma confinement in electron ring field reversed configuration (Cornell).	March 1978
14.	Complete proof-of-concept experiment for CO_2 laser heated solenoid (MSNW).	1979

Applied Plasma Physics

National Computer Network

3. Computer Services and Technology

	Projected Budget $K							
	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
Operating Budget	$ 3,200	$ 1,100	$ 5,000	$ 9,000	$ 8,700	$10,000	$10,000	$10,000
Equipment Budget	2,100	300	5,600	2,000	3,900	15,000	2,100	10,200
Construction Budget ...	0	0	5,000	0	0	0	0	0

Milestones

1.	Decision on acquisition of second CDC 7600.	April 1976 (Achieved)
2.	Complete Network operation.	June 1976 (Achieved)
3.	Begin construction of National MFE Computer Center Building (LLL).	Oct. 1976
4.	If decision on second CDC 7600 is positive, installation will occur (LLL).	Nov. 1976
5.	Install mass storage device (LLL).	Jan. 1977
6.	Decision on acquisition of Class VI Computer.	June 1977
7.	Complete construction of National MFE Computer Center building (LLL).	Jan. 1978
8.	If decision on Class VI computer is positive installation will occur (LLL).	early 1978

Applied Plasma Physics

Possible Future Experiments

LASL HBT	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
				Projected Budget $K				
Operating	$ 0	$ 0	$ 325	$ 1,015	$ 1,100	$ 1,200	$ 1,250	$ 1,300
Equipment	0	0	275	1,235	100	200	200	200
Construction	0	0	0	1,125	0	0	0	0

Milestones*

1. Complete Major Device Fabrication Review (MDFR) for HBT (LASL).	Nov. 1976
2. Complete assembly and test of a prototype (LASL).	Feb. 1978
3. Complete assembly of HBT (LASL).	Jan. 1979
4. Complete check out and begin initial operation (LASL).	July 1979

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*Assumes approval of the LASL HBT and the availability of FY 1977 funds.

Fast Liner Experiment	FY 1976	FY 1976T	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
	Projected Budget $K							
Operating	$ 0	$ 60	$ 620	$ 710	$ 3,300	$ 3,100	$ 2,200	$ 2,500
Equipment	0	0	120	2,650	2,850	275	200	20C

Milestones*

1.	Complete Major Device Fabrication Review (MDFR) for fast liner experiment (LX-1) (LASL).	Oct. 1976
2.	Begin modification of three racks of the Scyllac bank for fast liner experiment (LX-1) (LASL).	July 1976
3.	Begin LX-1 liner experiments on Scyllac bank (LASL).	Feb. 1977
4.	Begin design of fast liner experiment LX-2 (LASL).	Feb. 1978
5.	Complete MDFR for fast liner experiment LX-2 (LASL).	June 1978
6.	Begin construction of LX-2 (LASL).	Nov. 1978
7.	Begin operation of LX-2 (LASL).	Nov. 1980

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*Assumes approval of the LASL LX-1 and the availability of FY 1977 funds.

NOTE: The required funds for these two proposed LASL experiments are not included in the planned budgets for the Applied Plasma Physics Program at this time. However, funds are available in the planned DMFE budget. Starting one or both of these experiments will depend on the experiments' technical evaluation (MDFR) and the DMFE priorities.